Nonproliferation Impacts Assessment for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel

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TABLE OF CONTENTS

ES.0 EXECUTIVE SUMMARY ES-1
ES.1 Introduction ES-1
ES.2 Sodium-Bonded Spent Nuclear Fuel – Background ES-2
ES.3 Technology Options Considered In This Assessment ES-3
ES.4 Alternatives ES-4
ES.5 U.S. Nonproliferation Goals ES-5
ES.6 Evaluation Factors ES-5
ES.7 Conclusion ES-6

Part I: Introduction and Background of the Nonproliferation Impacts Assessment . Part I

1.0 BACKGROUND 1-1

2.0 SCOPE AND STRUCTURE OF ASSESSMENT 2-1
2.1 Scope and Approach to the Assessment 2-1
2.2 Structure and Organization of the Assessment 2-2
2.3 Amount and Characteristics of Sodium-Bonded Spent Nuclear Fuel Inventory 2-3
2.4 Technologies 2-9
2.5 Alternatives 2-10

Part II: Comprehensive Assessment of Electrometallurgical Treatment . . . . Part II

3.0 ELECTROMETALLURGICAL TREATMENT 3-1
3.1 History of Electrometallurgical Treatment 3-1
3.1.1 THE EXPERIMENTAL BREEDER REACTOR-II 3-2
3.1.2 THE INTEGRAL FAST REACTOR PROGRAM 3-2
3.1.3 RECENT DEVELOPMENTS IN ELECTROMETALLURGICAL TREATMENT 3-3
3.2 Applicability of Electrometallurgical Treatment to Sodium-Bonded Fuel 3-5
3.3 Technical Issues and Questions of Electrometallurgical Treatment Technology 3-7
3.3.1 CURRENT TECHNICAL STATUS OF ELECTROMETALLURGICAL TREATMENT FACILITIES AT ARGONNE NATIONAL LABORATORY-WEST 3-7
3.3.2 POTENTIAL OF ELECTROMETALLURGICAL TREATMENT TO SEPARATE PLUTONIUM FOR PRODUCTION OF NUCLEAR WEAPONS 3-8
3.4 Application of Export Law and Nonproliferation Policy to Electrometallurgical Treatment 3-10
3.5 Potential Use of Electrometallurgical Treatment in a Global Context 3-11
3.5.1 TECHNICAL AND POLICY FACTORS AFFECTING NONPROLIFERATION 3-11
3.5.1.1 Technical Factors 3-11
3.5.1.2 Policy Factors 3-12
3.5.2 NONPROLIFERATION EVALUATION OF ELECTROMETALLURGICAL TREATMENT IN A GLOBAL CONTEXT 3-13

TABLE OF CONTENTS (continued)

Part III: **Nonproliferation Assessment of Technology Options and Alternatives in the *Draft Environmental Impact Statement for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel*** . . . . . **Part III**

4.0 EXPLANATION OF NONPROLIFERATION POLICY FACTORS / FRAMEWORK 4-1
- 4.1 Technical Factors 4-1
- 4.2 Policy Factors 4-2

5.0 DESCRIPTION OF TECHNOLOGIES 5-1
- 5.1 Electrometallurgical Treatment 5-1
- 5.2 Plutonium-Uranium Extraction (PUREX) Process 5-2
- 5.3 High-Integrity Cans 5-4
- 5.4 Melt and Dilute 5-4
- 5.5 No Action 5-6
- 5.6 Special Safety and Health Considerations 5-6

6.0 EVALUATION OF TECHNOLOGIES IN THE U.S. CONTEXT AS SCOPED IN THE *DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE TREATMENT AND MANAGEMENT OF SODIUM-BONDED SPENT NUCLEAR FUEL* 6-1
- 6.1 Electrometallurgical Treatment 6-2
  - 6.1.1 TECHNICAL FACTORS 6-2
  - 6.1.2 POLICY FACTORS 6-4
- 6.2 Plutonium-Uranium Extraction (PUREX) Process 6-5
  - 6.2.1 TECHNICAL FACTORS 6-5
  - 6.2.2 POLICY FACTORS 6-5
- 6.3 High-Integrity Cans 6-6
  - 6.3.1 TECHNICAL FACTORS 6-6
  - 6.3.2 POLICY FACTORS 6-7
- 6.4 Melt and Dilute 6-7
  - 6.4.1 TECHNICAL FACTORS 6-7
  - 6.4.2 POLICY FACTORS 6-8
- 6.5 No Action 6-9
  - 6.5.1 TECHNICAL FACTORS 6-9
  - 6.5.2 POLICY FACTORS 6-10

7.0 EVALUATION OF THE *DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE TREATMENT AND MANAGEMENT OF SODIUM-BONDED SPENT NUCLEAR FUEL* ALTERNATIVES 7-1
- 7.1 Alternative 1: Electrometallurgical Treatment of All Fuel at Argonne National Laboratory-West 7-2
- 7.2 Alternative 2: Electrometallurgical Treatment of Driver Fuel at Argonne National Laboratory-West, High-Integrity Can Packaging of Blanket Fuel at Argonne National Laboratory-West 7-3
- 7.3 Alternative 3: Electrometallurgical Treatment of Driver Fuel at Argonne National Laboratory-West; Declad and Clean Blanket Fuel at Argonne National Laboratory, PUREX at the Savannah River Site 7-3

TABLE OF CONTENTS (continued)

7.4 Alternative 4: Electrometallurgical Treatment of Driver Fuel at Argonne National Laboratory-West, Melt and Dilute Blanket Fuel at Argonne National Laboratory-West 7-4
7.5 Alternative 5: Electrometallurgical Treatment of Driver Fuel at Argonne National Laboratory-West; Declad and Clean Blanket Fuel at Argonne National Laboratory-West, Melt and Dilute at the Savannah River Site 7-4
7.6 Alternative 6: Melt and Dilute All Fuel at Argonne National Laboratory-West 7-5
7.7 No Action Alternative 7-5

8.0 CONCLUSIONS 8-1

APPENDIX A REFERENCES A-1

APPENDIX B ACRONYMS B-1

APPENDIX C NONPROLIFERATION AND EXPORT CONTROL POLICY STATEMENT C-1

ES.0 EXECUTIVE SUMMARY

ES.1 Introduction

This document assesses the potential nonproliferation impacts that may result from the proposed treatment and management of sodium-bonded spent nuclear fuel by the U.S. Department of Energy (DOE or the Department). The Department is proposing treatment of sodium-bonded spent nuclear fuel in the *Draft Environmental Impact Statement for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel* (DOE/EIS-0306D) (Draft EIS), which evaluates six different alternatives for treating and managing sodium-bonded spent nuclear fuel, and a no action alternative.

This document is organized into three parts. Part I presents background and introductory information concerning the assessment. Part II focuses on electrometallurgical treatment (EMT) and provides a nonproliferation assessment of EMT in a global context. Part III examines the nonproliferation concerns related to the technologies and alternatives analyzed for treatment and management of sodium-bonded spent nuclear fuel in the Draft EIS.

This document emphasizes EMT for three reasons. First, EMT appears prominently in the alternatives the Department considered in the Draft EIS.[1] One alternative specifies EMT of all sodium-bonded, metal-based spent nuclear fuel. Four other alternatives specify EMT of the sodium-bonded driver fuel and other technologies for sodium-bonded blanket fuel. Only two Draft EIS alternatives (including No Action) specify treatment and management in a manner that does not require EMT for at least a portion of the fuel.

Second, examination of EMT in the Draft EIS is more comprehensive than the analysis of the other technologies and options. This is due, in part, to the maturity of the EMT technology and the relatively early stages of development of the other technologies, (*e.g.*, melt and dilute), which limits the level of analysis. The portions of this assessment addressing these other technologies, similar to the corresponding analyses in the Draft EIS, are based on assumptions about process- and design-specific factors, rather than actual process data, because such data have not yet been produced.

Third, EMT is a separations technology in an advanced state of development that can be adapted for use in either fuel-cycle or waste management applications (although the Department has no current plan to use this technology in either of these applications beyond the potential treatment of the sodium-bonded spent nuclear fuel inventory[2]). While the nonproliferation impacts of EMT components as part of the now abandoned Integral Fast Reactor (IFR) fuel cycle have been previously evaluated,[3] such impacts have not been

[1] The Notice of Intent to prepare the EIS identified EMT as the proposed action (64 Federal Register p. 8553, February 22, 1999). The Draft EIS does not identify a preferred alternative.

[2] *Federal Register*. "Notice of Intent To Prepare an Environmental Impact Statement for Electrometallurgical Treatment of Sodium-Bonded Spent Nuclear Fuel in the Fuel Conditioning Facility at Argonne National Laboratory-West, Idaho National Engineering and Environmental Laboratory, Idaho." Vol. 64, No. 34. February 22, 1999. Page 8555.

[3] Wymer, R.G., et al. *An Assessment of the Proliferation Potential and International Implications of the Integral Fast Reactor*. Martin Marietta Energy Systems, Inc. May 1992.

completely assessed in a waste management application or in comparison to other waste management technologies.[4] EMT differs from other technologies being considered by the Department. The other technologies either are well recognized as having proliferation-prone characteristics of separating fissile material (*e.g.*, Plutonium-Uranium Extraction (PUREX)), are clearly waste management technologies not capable of uranium or actinide separation (*e.g.*, high-integrity cans, melt and dilute), and/or are in comparatively early stages of development (*e.g.*, melt and dilute).

Part III of this document examines the proliferation potential of the five technology options and the seven alternatives identified in the Draft EIS.

The Department's Office of Arms Control and Nonproliferation has prepared this assessment. Together with the Draft EIS and an associated cost report, both being prepared by the Office of Nuclear Energy, this assessment is being made available to the public as part of the Department's decision-making process to evaluate reasonable alternatives for the treatment and management of sodium-bonded spent nuclear fuel.

ES.2 Sodium-Bonded Spent Nuclear Fuel – Background

The Department is responsible for the safe and efficient management of 250 different types of spent nuclear fuel, including ultimate disposition of the fuel, which is expected to be in a geologic repository. Some spent nuclear fuels may be suitable for disposal in a repository with little or no stabilizing treatment. Others, including sodium-bonded spent nuclear fuel, may require significant treatment or stabilization. The Department believes that treatment to remove metallic sodium and to convert sodium-bonded fuel into a compact waste form would reduce complications of repository disposal qualification and licensing.

The Draft EIS addresses approximately 60 metric tons heavy metal (MTHM) of sodium-bonded spent nuclear fuel, most of which resulted from breeder reactor development and support for the Detroit Edison Fermi Nuclear Power Plant. There are two types of sodium-bonded spent nuclear fuel: driver fuel and blanket fuel. Driver fuel is used mainly in the center of the reactor core to "drive" and sustain the fission chain reaction. It contains primarily uranium highly enriched in the isotope uranium-235. Blanket fuel is usually placed at the perimeter of the core and is used to breed the fissile material plutonium-239. About 93 percent by mass of heavy metal of the sodium-bonded fuel is blanket fuel.

Nearly all of the fuel (more than 59 MTHM of the 60 MTHM managed by DOE) in the inventory is currently in storage at the contiguous Argonne National Laboratory-West (ANL-W) and Idaho National Engineering and Environmental Laboratory (INEEL) sites managed by the Department. Table ES-1 presents an overview of the sodium-bonded spent nuclear fuel managed by the Department, including information on the types and quantities of fuel, the amount of plutonium (~280 kilograms) and highly enriched uranium (~3.4 metric tons) present in the fuel, and the radiation barriers surrounding the fuel.

[4] International Energy Associates Limited. *Nonproliferation Risks and Benefits of the Integral Fast Reactor.* IAEL-R/86-100. December 1986.

Table ES-1. DOE Inventory of Sodium-Bonded Spent Nuclear Fuel

Type	Site/Reactor [a]	Amount (MTHM)	Plutonium Content (kilograms) [c]	Gamma Dose at 1 Meter (rem/hour) for a Typical Fuel Assembly	
				Year 2000	Year 2035
Driver	EBR-II	3.1 [b]	19 [d]	56 - 60 [e]	23 - 24 [e]
	Hanford FFTF	0.3 [b]	3	390	156
Blanket	EBR-II	22	250	4	2
	Fermi-1	34	7	0.04	0.02
Miscellaneous	SNL, ORNL	0.1	Not Available	Not Available	Not Available
Total		**~60**	**~280**		

[a] Site of reactor where fuel was irradiated.
[b] Highly enriched uranium
[c] Plutonium content values are calculated estimates.
[d] Of the estimated 19 kg plutonium inventory for EBR-II drivers, 11 kilograms of plutonium are in the fuel stored at ANL-W and 8 kilograms of plutonium are in the fuel stored at INTEC.
[e] EBR-II drivers stored at ANL-W have typical gamma doses of 60 rem/hour (2000) and 23 rem/hour (2035). The corresponding values for EBR-II drivers stored at INTEC are 56 and 24 rem/hour.
EBR = Experimental Breeder Reactor
FFTF = Fast Flux Text Reactor
SNL = Sandia National Laboratory
ORNL = Oak Ridge National Laboratory

ES.3 Technology Options Considered In This Assessment

The five technologies being considered by the Department in the Draft EIS for treatment and management of sodium-bonded spent nuclear fuel are identified below.

Electrometallurgical Treatment. This technology is a separations technology that produces separated uranium as a final product. Spent nuclear fuel is chopped and placed in a molten salt mixture. An electric current is applied to the mixture, causing the uranium to collect on a cathode. The plutonium, transuranic elements, fission products, and the sodium present in the spent fuel dissolve in the salt. The mixture of plutonium and fission products is pressed into a ceramic high-level waste form. Undissolved cladding materials with residual fuel inside are cast into a metal high-level waste form. The collected uranium is melted (and diluted as necessary) to produce low-enriched uranium metal ingots.

Plutonium-Uranium Extraction Process. Using this technology, uranium and plutonium are separated from fission products and may be separated from each other. The technology uses a counter-current solvent extraction process. The fuel is first dissolved in nitric acid, and a subsequent solvent extraction process is used to separate the uranium, plutonium, and, depending on process chemistry, some or all of the neptunium from the fission products. The uranium and plutonium may be subsequently separated.

High-Integrity Cans. This is a packaging technology in which spent nuclear fuel would be packaged in cans constructed of a highly corrosion-resistant material (such as Hastelloy C-22) to provide long-term corrosion protection in a repository environment. The high-integrity can provides substitute cladding for damaged or declad fuel, or another level of containment for intact fuel. The can could be used to store fuel onsite until it is ready for shipment to a repository. Prior to such shipment, the high-integrity cans are placed into standardized stainless-steel canisters ready for disposal in waste packages. Prior to packaging, reactive sodium, if present, may be removed from the fuel. The fuel is vacuum dried and sealed in the cans.

Melt and Dilute. In this process, the fuel is melted, mixed with depleted uranium, if necessary, to isotopically reduce the uranium-235 concentration, alloyed with other metals, and cast into ingots, which are placed in canisters. The process may be adapted to fuel containing metallic sodium with further research and development.

No Action. Under this alternative, spent nuclear fuel is not treated but instead is continued to be stored pending a future disposition decision. As an option under this alternative, DOE would actively research and develop less mature technologies. Also, this alternative considers direct disposal of untreated blanket and driver fuel using high-integrity cans.

ES.4 Alternatives

Using the technologies described above, the Department has identified six potential alternatives to treat and manage its current inventory of sodium-bonded spent nuclear fuel, plus a no action alternative in which the fuel would continue to be stored with no treatment (Table ES-2). Each alternative includes either one or two of the technologies identified above, with driver and blanket fuels managed by either the same or different technologies.

Table ES-2. Proposed Alternatives

Technology		Alternatives						
		1	2	3	4	5	6	No Action
EMT at ANL-W		D & B	D	D	D	D		
PUREX at SRS				B				
High-Integrity Cans at ANL-W			B					
Melt and Dilute	SRS					B		
	ANL-W				B		D & B	
No Action								D & B

EMT = Electrometallurgical Treatment
ANL-W = Argonne National Laboratory-West
PUREX = Plutonium-Uranium Extraction Process
SRS = Savannah River Site
D refers to the driver sodium-bonded spent nuclear fuel.
B refers to the blanket sodium-bonded spent nuclear fuel.

ES.5 U.S. Nonproliferation Goals

This assessment evaluates the extent to which each technology option supports U.S. nonproliferation goals, which are summarized below.

- To reduce the risk of nuclear proliferation and for other considerations, the United States neither encourages the civil use of plutonium nor engages in plutonium reprocessing for either nuclear power or nuclear explosive purposes. In addition, the United States works actively with other nations to reduce global stocks of excess weapons-usable material: separated plutonium and highly enriched uranium (HEU). Under this policy, the United States honors its commitments to cooperate with civilian nuclear programs that involve the reprocessing and recycling of plutonium in Western Europe and Japan. In all such cases, however, the United States seeks to ensure that the International Atomic Energy Agency (IAEA) has the resources needed to implement its vital international safeguards responsibilities, and works to strengthen the IAEA's ability to detect clandestine nuclear activities. The United States seeks to eliminate where possible the accumulation of stockpiles of HEU and plutonium, and to ensure that where these materials already exist they are subject to the highest standards of safety, security, and international accountability. The United States also actively opposes, as do other supplier nations, the introduction of reprocessing and plutonium recycling activities in regions of proliferation concern.

- The United States also seeks to minimize the adverse environmental, safety, and health impacts of its management of nuclear materials and activities. This goal includes minimizing the generation of radioactive wastes and ensuring that waste materials are put into forms that can be disposed of safely.

ES.6 Evaluation Factors

To evaluate the extent to which the technology options support U.S. nonproliferation policy goals, this study evaluates the technology options and alternatives using three technical factors and four policy factors, as explained below.

The three technical factors include the degree to which a particular technology or alternative would:

- Help assure that the weapons-usable nuclear material in the spent nuclear fuel could not be stolen or diverted during the process. This evaluation includes assessing the attractiveness and accessibility of the material to potential overt or covert theft or diversion with respect to its characteristics both during and after processing.

- Facilitate cost-effective international monitoring.

- Result in converting spent nuclear fuel into a form from which retrieval of the material for weapons use would be difficult and unlikely.

The four policy factors include the degree to which a particular technology would:

- Be consistent with U.S. policy related to reprocessing and nonproliferation.

- Avoid encouraging other countries to engage spent nuclear fuel reprocessing, or undermining U.S. efforts to limit the spread of reprocessing technology and activities, particularly to regions of proliferation concern.

- Help demonstrate clearly that any treatment of these spent nuclear fuels will not represent the production by the United States of additional special nuclear material for use in nuclear weapons.

- Support negotiation of a nondiscriminatory global fissile material cutoff treaty (FMCT), including allowing for the possibility of verification approaches that would be acceptable to the United States.

Each of the technical and policy factors must be weighed in judging the relative nonproliferation merits of each option. In many cases, actions can be taken to mitigate proliferation concerns, but the degree of certainty in the success of these actions varies widely.

ES.7 Conclusion

Of the seven alternatives proposed in the Draft EIS, only one–that involving PUREX reprocessing at the Savannah River Site (SRS)–raises significant nonproliferation issues. All other alternatives, which include either electrometallurgical treatment, melt and dilute processing, canning, continued storage and deferred treatment, or combinations of these technology options, either fully meet U.S. nonproliferation objectives or have the potential to raise only limited concerns. The Office of Arms Control and Nonproliferation supports implementation of any of the remaining six non-PUREX alternatives. Some of the remaining six alternatives have marginal, but not decisive, advantages over others, but all are acceptable in terms of nonproliferation risk. Among these alternatives, the primary concern lies not with the specific actions proposed in the Draft EIS but with subsequent actions that may involve EMT. Specifically, as emerging technologies, such as EMT, capable of producing (or being adapted to produce) weapons-usable material continue to be identified, their continued use, export, development, and promotion could cause countries to question the U.S. commitment against reprocessing and provide encouragement for the expansion or initiation of reprocessing programs in other countries.

In summary:

- All alternatives could be implemented with a reasonable assurance against theft or diversion of weapons-usable materials.

- All alternatives could be made subject to international monitoring. However, international monitoring would be more difficult to implement at the SRS F-Canyon facility than at the other facilities.

- Except for plutonium metal produced from PUREX reprocessing, all final forms exhibit properties that would make retrieval of weapons-usable material reasonably difficult.

However, for all alternatives, the radiation barrier associated with final forms is much lower than that exhibited from commercial spent nuclear fuel.

- Spiking final forms with fission products from other sources, though not currently planned, could effectively increase the radiation barrier of the final forms and decrease their attractiveness for theft.

- Only one alternative–that involving PUREX reprocessing at SRS–results in an increase in weapons-usable fissile material inventories. However, the newly produced material would be managed with other surplus plutonium and would not become part of the domestic nuclear weapons inventory.

- All but one alternative–the one involving PUREX reprocessing at SRS–are fully consistent with U.S. policy with respect to reprocessing and nonproliferation.

- The alternatives including no action, canning, melt and dilute processing, and limited EMT (driver fuel only) provide no encouragement to other countries to engage in civilian or military plutonium reprocessing. In comparison, the alternatives involving PUREX reprocessing and broad application of EMT (*i.e.*, EMT of both driver and blanket fuel) have a greater potential to provide encouragement to countries to engage in plutonium reprocessing. Given the quantity and unique characteristics of the fuel and the reason for the treatment, however, such encouragement, if any, would be limited.

- All but one alternative–the one involving PUREX reprocessing at SRS–would build confidence that the United States is not producing materials for weapons. While it is generally recognized that the United States is no longer producing materials for weapons, the alternative involving PUREX reprocessing at SRS involves operation of a former weapons production facility and production of weapons-usable material.

- All alternatives would support negotiation of an FMCT, which would probably require some form of international monitoring at facilities capable of producing separated plutonium or highly enriched uranium. However, international monitoring would be more difficult to implement at the SRS F-Canyon facilities.

- Future actions involving technologies capable of producing (or being adapted to produce) weapons-usable material should be closely scrutinized to evaluate their consistency with their individual and cumulative impact on U.S. policy concerning reprocessing and nonproliferation.

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PART I: INTRODUCTION AND BACKGROUND OF THE NONPROLIFERATION IMPACTS ASSESSMENT

Part I, containing Chapters 1 and 2, provides an introduction to this assessment (Chapter 1) and contains background information (Chapter 2). Part I also describes the inventory of sodium-bonded spent nuclear fuel for which the Department of Energy (DOE or the Department) has management responsibility and identifies the technologies and alternatives being examined in the *Draft Environmental Impact Statement for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel* (DOE/EIS-0306D) to disposition this fuel.

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1.0 BACKGROUND

This document assesses the potential nonproliferation impacts that may result from proposed treatment and management of sodium-bonded spent nuclear fuel by the U.S. Department of Energy (DOE or the Department). The Department's Office of Arms Control and Nonproliferation has prepared this assessment. Together with a draft environmental impact statement[5] (Draft EIS) and an associated cost report, both being prepared by the Office of Nuclear Energy, this assessment is being made available to the public as part of the Department's decision-making process to evaluate several alternatives for the treatment and management of sodium-bonded spent nuclear fuel.

The Department of Energy is responsible for the safe and efficient management of 250 different types of spent nuclear fuel, including ultimate disposition of the fuel, which is expected to be in a geologic repository. Some spent nuclear fuels may be suitable for disposal in a repository with little or no stabilizing treatment. Others, including sodium-bonded spent nuclear fuel, may require significant treatment or stabilization. The Department believes that treatment to remove metallic sodium and to convert sodium-bonded fuel into a compact waste form would reduce complications of repository disposal qualification and licensing.

The electrometallurgical treatment (EMT) technique developed and demonstrated by the Department at Argonne National Laboratory-West (ANL-W) is one of several technologies being considered for treating sodium-bonded spent nuclear fuel. In a 1995 report, the National Academy of Sciences' National Research Council Committee on Electrometallurgical Techniques for DOE Spent Fuel Treatment recommended that the Department confirm the technical feasibility and cost effectiveness of EMT for processing its sodium-bonded spent nuclear fuel. The Department subsequently prepared the *Environmental Assessment for the Electrometallurgical Treatment Research and Demonstration Project in the Fuel Conditioning Facility at Argonne National Laboratory-West* (DOE/EA-1148) and issued a Finding of No Significant Impact on May 15, 1996. The demonstration project, which involves the electrometallurgical treatment of up to 1.6 metric tons heavy metal (MTHM) of sodium-bonded spent nuclear fuel, is scheduled to be completed in August 1999.

In anticipation of the successful completion of the demonstration project, the Department issued a Notice of Intent on February 22, 1999,[6] to prepare an environmental impact statement for the treatment and management of the remaining 60 MTHM of sodium-bonded spent nuclear fuel for which DOE has management responsibility. The Notice of Intent identified EMT at the Department's ANL-W Fuel Conditioning Facility and Hot Fuel Examination Facility as the proposed action to process this fuel. The Draft EIS assesses the impacts of using EMT and other technologies to manage this fuel, but does not specify a preferred alternative. The Department plans to issue the Draft EIS in July 1999.

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[5] *Draft Environmental Impact Statement for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel* (DOE/EIS-0306D).

[6] *Federal Register*. "Notice of Intent To Prepare an Environmental Impact Statement for Electrometallurgical Treatment of Sodium-Bonded Spent Nuclear Fuel in the Fuel Conditioning Facility at Argonne National Laboratory-West, Idaho National Engineering and Environmental Laboratory, Idaho." Vol. 64, No. 34. February 22, 1999. Page 8553.

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2.0 SCOPE AND STRUCTURE OF ASSESSMENT

In providing an overview of the nonproliferation impacts assessment, this chapter is organized into five sections.

- **Section 2.1** describes the scope of this assessment and the approach the Department used to perform it. It also provides the rationale for why this assessment focuses on electrometallurgical treatment (EMT).

- **Section 2.2** describes the structure and organization of this three-part document.

- **Section 2.3** describes the U.S. Department of Energy's (DOE or the Department) inventory of sodium-bonded spent nuclear fuel in terms of its physical configuration, chemical and radiological composition, fuel-type categorization, fissile content, quantity of fuel and material involved, origins of the fuel, and current locations of the inventory.

- **Section 2.4** identifies the technology options that DOE is considering to treat that inventory, as identified in the *Draft Environmental Impact Statement for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel* (DOE/EIS-0306D) (Draft EIS).

- **Section 2.5** identifies the alternatives DOE is considering to manage the fuel. These alternatives consist of specific combinations of management approaches and treatment technologies at designated DOE facilities, as described in the Draft EIS.

2.1 Scope and Approach to the Assessment

This document considers all of the technologies and alternatives analyzed in detail in the Draft EIS. It is organized into two related assessments. The first assessment (in Part II of this document) examines one technology, EMT, in a global context, and evaluates the technical and policy nonproliferation concerns raised by EMT. The second assessment (Part III of this document) examines the proliferation potential of the five technology options and the seven alternatives identified in the Draft EIS.

This document emphasizes EMT for three reasons. First, EMT appears prominently in the alternatives the Department considered in the Draft EIS.[7] One alternative specifies EMT of all sodium-bonded, metal-based spent nuclear fuel. Four other alternatives specify EMT of the sodium-bonded driver fuel and other technologies for sodium-bonded blanket fuel. Only two Draft EIS alternatives (including No Action) specify treatment and management in a manner that does not require EMT for at least a portion of the fuel.

Second, examination of EMT in the Draft EIS is more comprehensive than the analysis of the other technologies and options. This is due, in part, to the maturity of the EMT technology and the relatively early stages of development of other technologies, (*e.g.*, melt and dilute), which limits the level of analysis. The portions of this assessment addressing these other technologies, similar to the corresponding analyses in the Draft EIS, are based on assumptions about process- and design-specific factors, rather than actual process data, because such data have not yet been produced.

[7] The Notice of Intent to prepare the EIS identified EMT as the proposed action (64 FR 8553 February 22, 1999). The Draft EIS does not identify a preferred alternative.

Third, EMT is a separations technology in an advanced state of development that can be adapted for use in either fuel-cycle or waste management applications (although the Department has no current plan to use this technology in either of these applications beyond the intended treatment of the sodium-bonded spent nuclear fuel inventory[8]). While the nonproliferation impacts of EMT components as part of the now abandoned Integral Fast Reactor (IFR) fuel cycle have been previously evaluated,[9] such impacts have not been completely assessed in a waste management application or in comparison to other waste management technologies.[10] EMT differs from other technologies being considered by the Department. The other technologies either are well recognized as having proliferation-prone characteristics of separating fissile material (*e.g.*, Plutonium-Uranium Extraction (PUREX)), are clearly waste management technologies not capable of uranium or actinide separation (*e.g.*, high-integrity cans, melt and dilute), or are in comparatively early stages of development (*e.g.*, melt and dilute).

2.2 Structure and Organization of the Assessment

This report is divided into three parts, with the Part I containing Chapters 1 and 2.

- Chapter 1 provides an introduction to this report, specifies why the Department has prepared it, and specifies the overall objectives of the assessment.

- Chapter 2 contains background information on the assessment. It specifies the assessment scope and the approach the Department used to prepare this document. It also describes the inventory of sodium-bonded spent nuclear fuel covered by the assessment and the technology options and alternatives being considered to treat and manage the fuel.

Part II (Chapter 3) presents a comprehensive assessment of the nonproliferation issues associated with the EMT technology. Chapter 3 provides:

- A discussion on the origins and evolution of the EMT process;

- An analysis of the applicability of EMT to sodium-bonded spent nuclear fuel;

- A discussion of technically oriented nonproliferation issues and questions associated with the process, both in the context of this specific action as well as generically as either a fuel-cycle management or waste management technology; and

- A nonproliferation assessment of EMT technology in a global context with respect to seven technical and policy factors.

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[8] *Federal Register*, Vol. 64, No. 34. February 22, 1999. Page 8555.

[9] Wymer, R.G., et al. *An Assessment of the Proliferation Potential and International Implications of the Integral Fast Reactor.* Martin Marietta Energy Systems, Inc. May 1992.

[10] International Energy Associates Limited. *Nonproliferation Risks and Benefits of the Integral Fast Reactor*. IAEL-R/86-100. December 1986.

Part III (Chapters 4 through 8) of this report presents a comparative assessment of all technology options and alternatives considered in detail by the Department in the Draft EIS. This includes EMT as well as several other technologies and technology combinations:

- Chapter 4 describes the seven technical and policy factors relevant to U.S. nonproliferation efforts and this assessment.
- Chapter 5 presents a detailed description of all technology options analyzed in detail in the Draft EIS for treatment and management of sodium-bonded spent nuclear fuel.
- Chapter 6 presents a comparative assessment of the Draft EIS technology options based on the seven technical and policy factors described in Chapter 4.
- Chapter 7 provides a comparative assessment of the alternatives analyzed in the Draft EIS, based on the technology and management combinations of each alternative (explained below in Section 2.5), the assessment of technology options in Chapter 6, and the global assessment of EMT in Chapter 3 (Section 3.5.2).
- Chapter 8 outlines the conclusions of this assessment, including identifying some of the potential steps that could be taken to mitigate any nonproliferation disadvantages of the alternatives.

2.3 Amount and Characteristics of Sodium-Bonded Spent Nuclear Fuel Inventory

Table 2-1 presents information on the types and quantities of sodium-bonded spent nuclear fuel managed by the Department. Nearly all of the fuel (more than 59 of the 60 metric tons heavy metal (MTHM) managed by DOE) in the inventory, including all fuel from the Experimental Breeder Reactor-II (EBR-II) and Fermi-1 facilities, is currently in storage at the contiguous Argonne National Laboratory-West (ANL-W) and Idaho National Engineering and Environmental Laboratory (INEEL) sites managed by the Department.

In considering the nonproliferation impacts of the various technology options for the management of the approximately 60 MTHM of spent nuclear fuel, it should be noted that the material addressed in this assessment represents a small fraction of the spent nuclear fuel in the United States. The total amount of spent nuclear fuel projected to be managed in the DOE complex by 2035 is 2,556 MTHM. By contrast, domestic commercial nuclear power reactors are expected to produce a total of 86,700 MTHM of spent nuclear fuel by the end of their currently licensed operating lifetimes (see Figure 2-1).[11]

[11] United States Department of Energy. *Integrated Data Base Report–1996: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics.* DOE/RW-0006, Rev. 13. December 1997. Pages 1-7 and 1-11.

Figure 2-1. Amount of Spent Nuclear Fuel in the United States

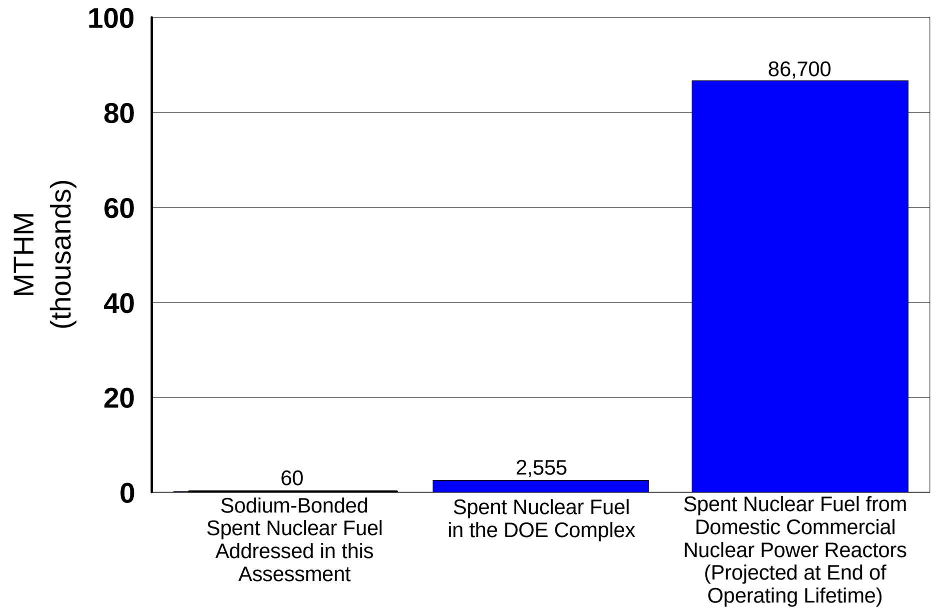


Table 2-1. DOE Inventory of Sodium-Bonded Spent Nuclear Fuel

Type	Site/Reactor	Amount (MTHM)
Driver	EBR-II	3.1
	Hanford FFTF	0.3
Blanket	EBR-II	22
	Fermi-1	34
Miscellaneous	SNL, ORNL	0.1
Total		**~60**

The DOE inventory of sodium-bonded spent nuclear fuel consists of predominantly all-metal fuels, most of which were generated as part of the breeder reactor program or in support of the Detroit Edison Fermi Nuclear Power Plant.[12] The breeder sodium-bonded fuel is composed of two categories of spent nuclear fuel: driver fuel and blanket fuel. Driver fuel is used mainly in the center of the reactor core to "drive" and sustain the fission chain reaction. It contains primarily uranium highly enriched in the isotope uranium-235. Blanket fuel is usually placed at the perimeter of the core and is used to breed the fissile material plutonium-239. It primarily contains the nonfissile, but fertile, isotope uranium-238 (in the form of depleted uranium), which converts to fissile plutonium-239 after the absorption of a neutron. In some cases, as in the case of EBR-II,

[12] Of the 60 MTHM inventory, 0.08 MTHM is in a non-metal form of either oxide, carbide, or nitride.

blanket fuel has also been used at the perimeter of the core for shielding. About 93 percent (by mass of heavy metal) of the sodium-bonded fuel is blanket fuel.

One of the technical problems encountered with driver fuel, and other fuels subject to high burnup, is finding the proper balance between burnup, heat transfer characteristics, and radiation damage to the fuel materials.[13] Typically, ceramic fuel matrices (oxides and carbides) are significantly more resistant to damage than all-metal fuel designs. Ceramics, however, are less dense and have relatively poor heat transfer characteristics. By sodium bonding the all-metal fuel, the effect of radiation damage, including the creation of void spaces and swelling within the fuel caused primarily by fission and other neutronic reactions, is mitigated by the presence of the liquid sodium, which fills the void spaces in the fuel matrix allowing it to swell without deleterious effect.

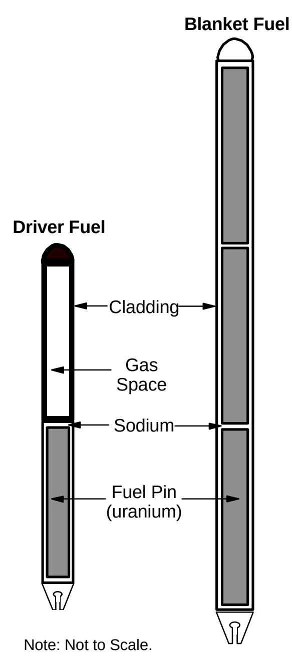
Figure 2-2 shows the sodium bonding scheme conceptually. Each individual fuel element is a stainless-steel cladding tube containing a metal-alloy fuel pin or pins, which is wetted by a sodium-bond material to provide good thermal contact between the fuel pin and the cladding. A gas plenum (void space) at the top of the fuel pin allows gaseous fission products escaping from the fuel matrix to collect above the active region. At maximum burnup, these fission gases contained in the plenum are at high pressure. Driver elements have a proportionally large gas plenum volume whereas blanket elements have a smaller proportional plenum space. This difference is due to the relatively small amount of fission gases that evolve in the blanket elements as opposed to the driver elements. Driver elements have a smaller radius and length than blanket elements.

When driver fuel is irradiated in the reactor for some period of time, pores form throughout the fuel. During this process, the pores expand and connect to one another; sodium flows into the pores; and some pores are closed off from the fuel surface, including those containing sodium. As a result, some of the sodium in the pores becomes inseparable from the uranium except by dissolving or melting the fuel.

A group of fuel elements is packed together in a hexagonal stainless duct, which has mounting points for the fuel elements and coolant flow manifolds at either end. Each fuel element has a spiral wire spacer affixed on the outside wall, which is used to provide space for liquid sodium coolant to flow between adjacent fuel elements within the duct to remove the heat of reaction. This combination of duct and fuel elements is referred to as the fuel assembly.

Of the 60 MTHM of sodium-bonded spent nuclear fuel in the inventory, about 99.5 percent of the heavy metal consists of uranium isotopes. Uranium in the 57 MTHM of blanket fuel is depleted uranium containing uranium-235 concentrations between 0.18 percent and 0.35 percent. The driver fuel contains about 3.3 MTHM of highly enriched uranium (HEU) with

Figure 2-2. Schematic Drawing of EBR-II Fuel Element



[13] The level of burnup is in proportion to the fissioned material in the fuel.

uranium-235 enrichment levels varying between 60 percent and 64 percent.[14] The balance of the heavy metal inventory includes 280 kilograms (0.05 percent) of plutonium and 1 kilogram of minor actinides. In addition, the fuel includes about 1.2 metric tons of fuel alloy materials: zirconium, molybdenum and fissium (an alloy that chemically mimics the behavior of metallic fission products). Table 2-2 shows a typical fissile material isotopic breakdown for the EBR-II spent fuel assemblies.

Table 2-2. Typical Fissile Material Isotopic Content of EBR-II Fuel

Isotope or Element	EBR-II Driver Fuel	EBR-II Blanket Fuel
Total Uranium (g) per Assembly	*3,978*	*46,137*
Uranium-234 (wt%)	0.7	0.00002
Uranium-235 (wt%)	64.2	0.2
Uranium-236 (wt%)	1.6	0.007
Uranium-238 (wt%)	33.5	99.8
Total Plutonium (g) per Assembly	*13*	*585*
Plutonium-238 (wt%)	0.2	0.004
Plutonium-239 (wt%)	99.0	98.1
Plutonium-240 (wt%)	0.8	1.9

Even though the sodium-bonded driver fuel was produced for and used in the Department's discontinued Integral Fast Reactor (IFR) program, the composition of the sodium-bonded driver fuel in DOE's inventory is different from driver fuel that would have been produced in a normal IFR fuel cycle. This difference occurs because the existing driver fuel was used in a single-pass operation rather than in a closed fuel cycle (as was visualized in the IFR concept). The driver pins are an alloy of HEU and zirconium rather than plutonium, depleted uranium, and zirconium, as would have been produced in a normal IFR fuel cycle.

The single-pass operation accounts for the isotopic composition of plutonium produced in the driver pins, which is high in plutonium-239. Sometimes, because of the selectivity for production of plutonium-239, the fuel is referred to as low burnup. In a fast breeder reactor, the high selectivity for production of plutonium-239 is more a function of the hard neutron spectrum and less a function of the degree of burnup. As illustrated in Table 2-2, the plutonium-239 concentration in blanket fuel is approximately 1 percent of the corresponding uranium-238 concentration. This concentration is clearly much higher than the typical 0.05 percent plutonium-239 content in low burnup conventional graphite production reactor spent nuclear fuel. If the plutonium production were recycled many times, higher plutonium isotopes and actinides would eventually accumulate in the fuel; but in single-pass operation, this accumulation has not yet occurred. The plutonium containing a high proportion of the plutonium-239 isotope present in EBR-II fuel is sometimes referred to as "ivory" or "super" grade plutonium among nuclear weapons analysts. This designation is given when greater than 98 percent of the plutonium is the plutonium-239 isotope. Recycling plutonium from driver fuel in the IFR fuel cycle has no effect on plutonium-239 production in blanket pins, which always produce weapons-grade (or better) plutonium.

[14] A small group of EBR-II control rods contains uranium enriched above 73 percent uranium-235. These rods were 78 percent enriched when fresh.

Table 2-3 shows the current and future gamma doses for the sodium-bonded spent nuclear fuel inventory. Radioactivity of the spent nuclear fuel drops with time as fission products decay (primarily cesium-137 which has a half-life of 33 years). Figure 2-3 shows a diagram of acute (or immediate) radiation effects on human health. The figure has two axes: the upper shows the dose rate in rem/hour (radiation exposure per unit time) and the lower shows the accumulated or total acute dose in rem (total radiation exposure). The radioactivity of the spent nuclear fuel is expressed as a dose rate at a given distance (rem/hour at 1 meter), whereas the immediate health effects are related to the accumulated acute dose (rem). Therefore, the immediate health consequence to a person handling radioactive materials depends on the material radioactivity, how long the material is handled, and the distance between the material and the person. Shielding reduces the dose rate at a given distance depending on the shield's ability to absorb radiation, with shield density and thickness being the primary factors. The radioactivity of the EBR-II spent fuel types is shown superimposed on the dose rate axis assuming measurement at a one-meter distance. Long-term effects of radiation doses on human health (such as an increase in cancer probabilities) are not shown in Figure 2-3 as they are not considered relevant to reduction of theft risk.

Table 2-3. Characteristics of Sodium-Bonded Spent Nuclear Fuel Inventory

Type	Site/Reactor [a]	Amount (MTHM)	Plutonium Content (kilograms) [c]	Gamma Dose at 1 Meter (rem/hour) for a Typical Fuel Assembly	
				Year 2000	Year 2035
Driver	EBR-II	3.1 [b]	19 [d]	56 - 60 [e]	23 - 24 [e]
	Hanford FFTF	0.3 [b]	3	390	156
Blanket	EBR-II	22	250	4	2
	Fermi-1	34	7	0.04	0.02
Miscellaneous	SNL, ORNL	0.1	Not Available	Not Available	Not Available
Total		**~60**	**~280**		

[a] Site of reactor where fuel was irradiated.
[b] Highly enriched uranium
[c] Plutonium content values are calculated estimates.
[d] Of the estimated 19 kg plutonium inventory for EBR-II drivers, 11 kilograms of plutonium are in the fuel stored at ANL-W and 8 kilograms of plutonium are in the fuel stored at INTEC.
[e] EBR-II drivers stored at ANL-W have typical gamma doses of 60 rem/hour (2000) and 23 rem/hour (2035). The corresponding values for EBR-II drivers stored at INTEC are 56 and 24 rem/hour.
FFTF = Fast Flux Text Reactor; SNL = Sandia National Laboratory; ORNL = Oak Ridge National Laboratory

The Spent Fuel Standard

The National Academy of Sciences recommended the Spent Fuel Standard in 1994. Meeting the Spent Fuel Standard means making a material approximately as inaccessible and unattractive for weapons use as the much larger and growing inventory of plutonium that exists in spent nuclear fuel from commercial nuclear power reactors. Spent nuclear fuel from commercial power reactors is unattractive for several reasons, including its high radiation barrier, large size, and physical and chemical composition, which make it difficult to transport, conceal, and process. The Spent Fuel Standard is a broad target area, not a single point on an imaginary graph of proliferation resistance, and can take into account any number of factors affecting accessibility and attractiveness. In the January 21, 1997, Record of Decision for the Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement (62 Federal Register 3014), DOE adopted the Spent Fuel Standard specifically for the disposition of weapons-usable fissile materials.

Only a portion of the plutonium and highly enriched uranium present in DOE's inventory of sodium-bonded spent nuclear fuel may meet the Spent Fuel Standard. In addition, after treatment and management under the Department's proposed action, only a portion of the plutonium and highly enriched uranium in the final forms will likely meet the standard. Of principal concern is the radiation barrier of the fuel, which varies over a broad range. Most of the plutonium is present in blanket fuel, which carries a radiation level (up to 4 rem/hour at one meter) far below what is considered highly radioactive (about 100 rem/hour). In contrast, the highly enriched uranium is present only in the sodium-bonded driver fuels (and a small quantity of miscellaneous fuels) having higher radiation levels (56 to 390 rem/hour at one meter) more likely to pose a deterrent to theft.

Approaches to making fissile material less attractive for weapons use include increasing the radiation barrier surrounding the material, isotopically diluting uranium by the addition of depleted uranium, chemically diluting uranium or plutonium so that they are present in very low concentrations, and converting the material into chemical forms from which extraction of fissile material is difficult (*e.g.*, some ceramic forms).

One approach to increasing the radiation barrier (and decreasing the attractiveness) of the plutonium-containing final forms resulting from blanket fuel processing (either by EMT, melt and dilute, or high-integrity cans) is to "spike" the final forms with highly radioactive fission products (*e.g.*, cesium-137) from other sources. While such an approach would decrease the theft risk of the final form, it would also be expected to affect the overall environmental impact and cost of the action.

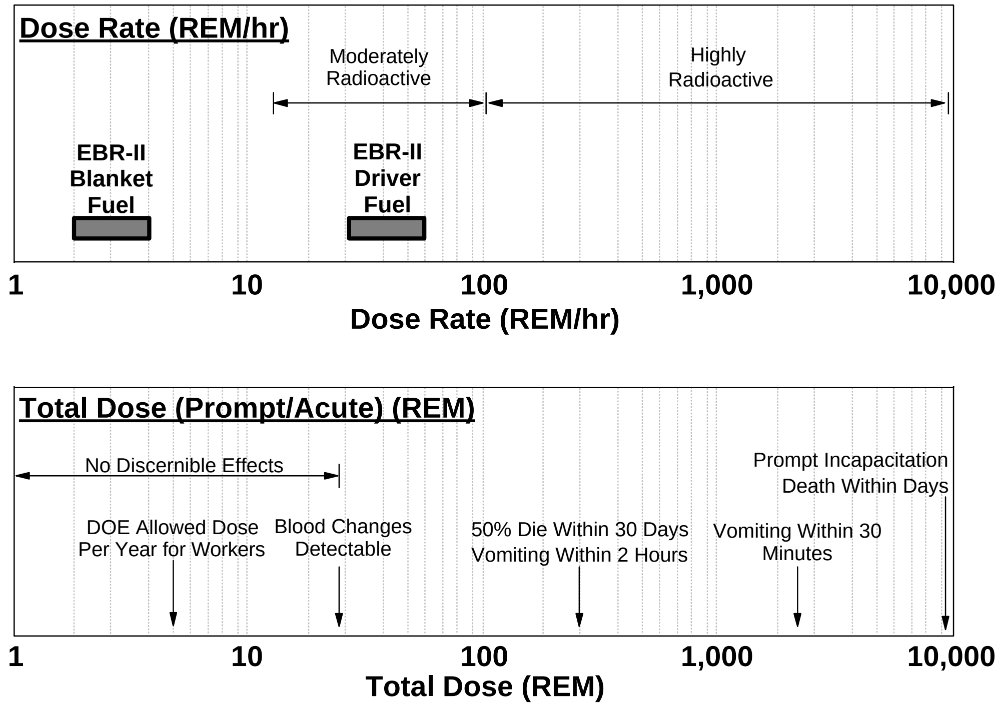
The immediate health consequences of high doses of whole-body radiation represent a significant barrier to theft of highly radioactive materials, and this characteristic is one of the major considerations of the Spent Fuel Standard, a concept developed to evaluate the potential proliferation concerns of nuclear materials (see text box). Operations involving such materials require heavy shielding and remote handling equipment. The International Atomic Energy Agency (IAEA) considers all materials above 100 rem/hour at one meter to be "highly radioactive" and "self-protecting."[15] This threshold only allows a few minutes of close contact before noticeable blood changes occur (above 25 rem of acute dose, a blood test will indicate exposure). DOE considers whole body doses above 15 rem/hour at one meter to cause a significant reduction in risk of theft and 100 rem/hour at one meter to essentially rule out theft as a principal risk consideration.[16] However, under either of these criteria, none of the sodium-bonded blanket fuel is considered self-protecting. In fact,

[15] International Atomic Energy Agency. *The Physical Protection of Nuclear Material*. INFCIRC/225/Rev. 3. September 1993.

[16] U.S. Department of Energy. *Guide for the Implementation of DOE Order 5633.3b, Control and Accountability of Nuclear Materials*. Page 1-4.

the Fermi blankets (0.04 rem/hour at one meter) could be safely handled within conservative DOE regulations on occupational dose (less than 5 rem whole body dose per year).

Figure 2-3. Effects of Radiation on Human Health



2.4 Technologies

The five technologies being considered by the Department in the Draft EIS for treatment and management of sodium-bonded spent nuclear fuel are identified below. These technologies are described in further detail in Chapter 5.

Electrometallurgical Treatment. This technology is a separations technology that produces separated uranium metal as a final product. Spent nuclear fuel is chopped and placed in a molten salt mixture. An electric current is applied to the mixture, causing the uranium to collect on a cathode. The plutonium, transuranic elements, fission products, and bond sodium dissolve in the salt. The salt mixture containing plutonium and fission products is pressed into a ceramic high-level waste form. Undissolved cladding materials with residual fuel inside are cast into a metal high-level waste form. The collected uranium is melted (and diluted as necessary) to produce low-enriched uranium metal ingots.

Plutonium-Uranium Extraction Process. Using this technology, uranium and plutonium are separated from fission products and may be separated from each other. The technology uses a counter-current solvent extraction process. The fuel is first dissolved in nitric acid, and a subsequent solvent extraction process is used to separate the uranium, plutonium, and, depending on process chemistry, some or all of the neptunium from the fission products. The uranium and plutonium may be subsequently separated.

High-Integrity Cans. This is a packaging technology in which spent nuclear fuel would be packaged in cans constructed of a highly corrosion-resistant material (such as Hastelloy C-22) to provide long-term corrosion protection in a repository environment. The high-integrity can provides substitute cladding for damaged or declad fuel, or another level of containment for intact fuel. The can could be used to store fuel onsite until it is ready for shipment to a repository. Prior to such shipment, the high-integrity cans are placed into standardized stainless-steel canisters ready for disposal in waste packages. Prior to packaging, reactive sodium, if present, may be removed from the fuel. The fuel is vacuum dried and sealed in the cans.

Melt and Dilute. In this process, the fuel is melted, mixed with depleted uranium, if necessary, to isotopically reduce the uranium-235 concentration alloyed with other metals, and cast into ingots, which are placed in canisters. The process may be adapted to fuel containing metallic sodium with further research and development.

No Action. Under this alternative, spent nuclear fuel is not treated but instead is continued to be stored pending a future disposition decision. As an option under this alternative, DOE would actively research and develop less mature technologies. Also, this alternative considers direct disposal of untreated blanket and driver fuel using high-integrity cans.

2.5 Alternatives

Using the technologies described above, the Department has identified six potential alternatives to treat and manage its current inventory of sodium-bonded spent nuclear fuel, plus a no action alternative in which the fuel would continue to be stored with no treatment (Table 2-4). Each alternative includes either one or two of the technologies identified above, with driver and blanket fuels managed by either the same or different technologies.

Table 2-4. Proposed Alternatives

Technology		Alternatives						
		1	2	3	4	5	6	No Action
EMT at ANL-W		D & B	D	D	D	D		
PUREX at SRS				B				
High-Integrity Cans at ANL-W			B					
Melt and Dilute	SRS					B		
	ANL-W				B		D & B	
No Action								D & B

EMT = Electrometallurgical Treatment
ANL-W = Argonne National Laboratory-West
PUREX = Plutonium-Uranium Extraction Process
SRS = Savannah River Site
D refers to the driver sodium-bonded spent nuclear fuel.
B refers to the blanket sodium-bonded spent nuclear fuel.

PART II: COMPREHENSIVE ASSESSMENT OF ELECTROMETALLURGICAL TREATMENT

Part II presents a comprehensive assessment of the nonproliferation issues associated with the electrometallurgical treatment (EMT) technology. Electrometallurgical treatment appears prominently in the alternatives considered by the U.S. Department of Energy in the *Draft Environmental Impact Statement for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel* (DOE/EIS-0306D) (Draft EIS). One alternative specifies EMT of all sodium-bonded, metal-based spent nuclear fuel. Four other alternatives specify EMT of the sodium-bonded driver fuel and other technologies for the sodium-bonded blanket fuel. Only two alternatives analyzed in the Draft EIS (including No Action) specify treatment and management in a manner that does not require EMT for at least a portion of the fuel.

The analysis in Part II provides information on the origins and evolution of the EMT process, the applicability of the process to sodium-bonded spent nuclear fuel, the nonproliferation issues or questions associated with the process, both in the context of this specific action as well as generically as either a fuel-cycle or waste management technology, and a nonproliferation assessment of the EMT technology in a global context with respect to several technical and policy factors.

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3.0 ELECTROMETALLURGICAL TREATMENT

This chapter presents a comprehensive assessment of the potential nonproliferation impacts associated with the use of electrometallurgical treatment (EMT), including separate analyses addressing technical and policy issues.

- Section 3.1 provides a brief history of the origins and evolution of the EMT technology.
- Section 3.2 describes the applicability of EMT to sodium-bonded spent nuclear fuel.
- Section 3.3 presents a focused technical review of EMT with respect to nonproliferation issues, both in terms of the current proposed action as well as the generic EMT technology.
- Section 3.4 presents an analysis of the EMT technology with respect to export law and U.S. nonproliferation policy.
- Section 3.5 provides a nonproliferation assessment of the EMT technology in a global context taking into account predefined technical and policy factors.

3.1 History of Electrometallurgical Treatment

Electrometallurgical treatment of spent nuclear fuel at the U.S. Department of Energy's (DOE or the Department) Argonne National Laboratory has been under development since the early 1980s. A report by the National Academy of Sciences described the EMT process as follows:

> *The electrometallurgical technology under development at [Argonne National Laboratory] is derived from many years of R&D on molten salt systems for the production of materials for nuclear reactors and weapons....The heart of the process is the electrorefining step, which employs a metallic feed, molten alkali metal salts as the reaction medium, and two cathodes, one steel and the other an immiscible pool of molten cadmium, to separate actinides from fission products and other nuclear reactor fuel materials.*[17]

The electrorefiner[18] was originally designed to serve as the reprocessing component of the Department's Integral Fast Reactor (IFR) Program, begun in 1983. The IFR Program was comprised of two main components: the breeder reactor and the electrorefiner.

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[17] National Research Council. *An Assessment of Continued R&D into an Electrometallurgical Approach for Treating DOE Spent Nuclear Fuel*, S-2. 1995. In the current EMT configuration at ANL-W, the molten cadmium cathode is not present in the electrorefiner.

[18] An electrorefiner exploits the difference in electrochemical properties between various metal ions in an electrolyte (salt) solution to selectively separate a given metal at the surface of a cathode by means of a reduction reaction. The reduced metal forms a solid deposit on the cathode which can then be physically separated from the electrolyte solution. In the case of the EMT process, the separated metal (the "electrorefined" metal) is uranium, with plutonium and other metal ions remaining in the electrolyte solution.

3.1.1 THE EXPERIMENTAL BREEDER REACTOR-II

The Experimental Breeder Reactor-II (EBR-II), located at the Department's Argonne National Laboratory-West (ANL-W) site, was constructed between June 1958 and May 1961. The original emphasis in the design and operation of the EBR-II was to demonstrate a complete breeder-reactor power plant with on-site reprocessing of metallic fuel. The EBR-II successfully completed a demonstration from 1964 to 1969, after which emphasis shifted to testing fuel and materials for future, larger, liquid-metal-cooled reactors in the radiation environment of the EBR-II reactor core.[19]

As nuclear power and technology expanded worldwide during the 1970s and 1980s, the United States took the initiative to strengthen the nonproliferation regime by unilaterally halting the domestic civilian reprocessing of spent nuclear fuel and the commercial use of separated plutonium. Among other steps, taking into account an international study entitled, "The International Nuclear Fuel Cycle Evaluation," published in 1980, the United States sought to develop advanced nuclear technologies that did not involve the separation of pure plutonium.[20]

3.1.2 THE INTEGRAL FAST REACTOR PROGRAM

Responding to this policy, beginning in 1983, the United States undertook to develop the IFR recycle technology.[21] In conjunction with the electrorefiner and other unit processes, the EBR-II formed a breeder fuel cycle to recycle plutonium under the IFR concept. DOE never developed the IFR process beyond a pilot-scale level.[22]

Plutonium Recycling and HEU in the IFR

The Integral Fast Reactor (IFR) concept was developed by DOE as an efficient method of producing and recycling plutonium in nuclear reactors. While the United States does not currently reprocess and recycle separated plutonium produced in commercial power reactors, other countries do using the so-called Plutonium-Uranium Extraction (PUREX) process, which separates out plutonium. The commercial processes in use now and in the past have involved a complex system in which reactors, plutonium recovery facilities, and plutonium fuel fabrication facilities are located at separate sites and independently operated. In this fuel cycle, the recovered plutonium provides only a small fraction of the nuclear fissioning power that sustains the reactors, which must continue to be supplied with new uranium fuel.

The IFR concept is different from the commercial plutonium recycling processes currently in use in other countries. In the IFR concept, the reactor is a self-sustaining breeder reactor that produces all of the plutonium fuel it consumes. The IFR breeder reactor converts depleted uranium feed into plutonium in a uranium blanket surrounding a reactor core of driver fuel. In addition, the IFR concept envisioned collocation and coordinated operation of one or more breeder reactors, facilities to extract fissile material from the spent fuel, and facilities to cast the separated fissile material into new fuel. Another difference is that the IFR did not separate pure plutonium; instead, it prepared fuel from a uranium-plutonium mixture that was contaminated with highly radioactive fission products. While a mature IFR system is fueled with plutonium, the core of a newly started IFR could be fueled with either highly enriched uranium (HEU) or plutonium. The sodium-bonded EBR-II driver fuel in the Department's inventory contains HEU and is similar to driver fuel that would be used in a newly started IFR.

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[19] ANL-W History - Reactors (EBR-II). Http://www.anlw.anl.gov/htdocs/anlw_history/reactors/ebr_ii.html

[20] Hannum, W.H., et al. *Progress in Nuclear Energy*. Vol. 31, No. 1/2, 1996. Pages 204-205.

[21] *Id.* at 205.

[22] Till, C.E., et al. *The Integral Fast Reactor - An Overview, Progress in Nuclear Energy*. Vol.31, No. 1/2, 1997. Pages 3-11.

Approximately 2,300 kilograms of EBR-II spent driver fuel was recycled using a different pyrometallurgical technique (not related to the electrometallurgical process) known as "melt refining" conducted between 1964 and 1969.[23] None of the IFR process configurations (using either the melt refining or the electrometallurgical processes) included the complete separation of plutonium at any point in the fuel cycle. The EBR-II served as the IFR prototype reactor during the 1980s during which it was used to conduct passive safety experiments.

Pyroelectrometallurgical Processing v. Electrometallurgical Treatment

The pyroelectrometallurgical reprocessing (or pyroprocessing) was developed for the Integral Fast Reactor (IFR) Program to serve as a process for recovering actinide elements (plutonium) from spent nuclear fuel and recycling them, along with some fission products, to the IFR as fuel materials.

The electrometallurgical treatment process addressed in this analysis contains only a subset of the equipment required for pyroprocessing. The important technologies in question are electrorefiners, cathode processors (salt stills) and casting furnaces. Instead of producing recycled fuel for reactors, electrometallurgical treatment is designed to produce final waste forms appropriate for geologic disposal. In this case, plutonium is never separated from high-level waste products.

As confidence that uranium supplies were sufficient to fuel nuclear power for decades increased during the 1980s and early 1990s, and it therefore became clear that plutonium breeding and recycling would not be economic for a substantial period, a number of countries, including the United States, reassessed their breeder reactor development programs.[24] The IFR changed its focus to emphasize use of the system for transmutation of long-lived radioactive wastes, but a National Academy of Sciences' review raised serious questions concerning the use of the IFR for this mission. Moreover, continued U.S. research and development emphasis on developing technology for reprocessing and recycling plutonium–even technologies more proliferation-resistant than the Plutonium-Uranium Extraction (PUREX) reprocessing technology in wide commercial use–at a time when there was no requirement for such recycling to extend fuel supplies, was seen as potentially encouraging other countries to continue or expand their plutonium reprocessing and recycling programs, undermining the U.S. policy not to encourage plutonium reprocessing. Hence, U.S. funding for the IFR program was phased out in 1994. The IFR program was officially shut down on September 30, 1994, but work on pyrometallurgical processing for a variety of waste management missions (from which the current EMT technology developed) continued.

3.1.3 RECENT DEVELOPMENTS IN ELECTROMETALLURGICAL TREATMENT

In 1992, the U.S. Departments of State and Energy conducted a study analyzing the potential proliferation concerns of the IFR process.[25] After the cancellation of the IFR Program in 1994, the major driver of the pyroelectrometallurgical process development shifted from developing a breeder fuel-cycle technology for

[23] Benedict, M., et al. *Nuclear Chemical Engineering*. 2nd Edition, McGraw Hill, 1981. Page 464.

[24] Britain and Germany also ended their financial support for fast reactor development programs in the 1990s. Japan delayed commercialization of its fast reactor and temporarily shut down the existing prototype after an accident. Russia stopped construction of its new breeder system for lack of funding. France recently decided to close its Superphenix prototype fast neutron reactor, while keeping the smaller and older Phenix system running for transmutation experiments. No country in the world currently has a funded program to commercialize a breeder reactor system.

[25] Wymer, R.G., et al. *An Assessment of the Proliferation Potential and International Implications of the Integral Fast Reactor.* Martin Marietta Energy Systems, Inc. May 1992.

fast reactors to production of final waste forms appropriate for geologic disposal. This waste management flowsheet is now referred to as EMT. Since then, the Department has continued to refine EMT processes originally developed for the IFR program.

In adapting the IFR process to EMT, the electrorefiner was modified by eliminating the cadmium cathode used to collect a uranium-plutonium alloy for future use in the IFR breeder fuel cycle. Instead, the plutonium in the spent nuclear fuel becomes part of a salt mixture that is then immobilized in a zeolite and converted to a ceramic waste form suitable for final disposal.

In September 1994, in order to assess the viability of EMT for spent nuclear fuel, the Department requested the National Academy of Sciences to perform an independent evaluation of the technology, based on the assumption that DOE intended to begin immediate treatment of 270 EBR-II spent driver fuel assemblies and 326 spent blanket fuel assemblies stored at the ANL-W site in Idaho. The National Academy of Sciences' National Research Council Committee on Electrometallurgical Techniques for DOE Spent Fuel Treatment issued its report in June 1995 with the following recommendation:

> *[Argonne National Laboratory] should proceed with its development plan in support of the EBR-II demonstration . . . If the EBR-II demonstration [program] is not accomplished successfully, the . . . program on electrometallurgical processing should be terminated. On the other hand, if the EBR-II demonstration is successful, the DOE should revisit the [electrometallurgical] program at that time in the context of a larger, "global" waste management plan to make a determination for possible continuance.*[26]

Consistent with this recommendation, the Department decided to conduct a research and demonstration project before considering using EMT to process its inventory of 596 EBR-II spent fuel assemblies. On May 15, 1996, the Department issued an environmental assessment for a proposed research and demonstration project for using EMT for EBR-II spent nuclear fuel. The project involved EMT processing of up to 100 EBR-II spent driver assemblies and 25 spent blanket assemblies in the Fuel Conditioning Facility at ANL-W. Completion of the demonstration project is expected in August 1999, at which time the Department plans to decide how to manage the remaining EBR-II spent nuclear fuel as well as similar spent nuclear fuel from other liquid-metal-cooled reactors for which the Department is responsible.

Assessment of the proliferation risks of EMT has continued in recent years. According to ANL-W:

> *The IFR pyroprocess was designed to be 'proliferation resistant.' Simply put, this means that fuel recycled with IFR technology can't be easily used as material for nuclear weapons. Attempts to extract material to produce a nuclear weapon would require a huge, easily detectable, investment in the same type of facilities and equipment that would be required to produce the material directly from spent fuel from any type of reactor.*[27]

However, the National Academy of Sciences' National Research Council Committee on Electrometallurgical Techniques for DOE Spent Fuel Treatment noted the following concerns:

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[26] National Research Council. *An Assessment of Continued R&D into an Electrometallurgical Approach for Treating DOE Spent Nuclear Fuel*. 1995. Page S-11.

[27] ANL-W History - Reactors (IFR). Http://www.anlw.anl.gov/htdocs/anlw_history/reactors/ifr.html

> *Although the developers of the electrometallurgical technique argue that the technology is proliferation resistant, any [spent nuclear fuel] processing approach that is capable of separating fissionable materials from associated fission products and transuranic elements could be redirected to produce material with nuclear detonation capability.*[28]

In another report, the aforementioned committee offered its view of proliferation problems associated with pyroprocessing spent nuclear fuel:

> *Developing technology that effectively extracts the plutonium from mixtures could facilitate decommissioning of former weapons manufacturing facilities and mitigate some of the problems found at these facilities, such as corroding fuel. However, such efficient technology also raises concerns about proliferation; what the United States might use to assist in the cleanup of a contaminated facility such as Rocky Flats could be used by another country to obtain plutonium for a weapons program.*[29]

3.2 Applicability of Electrometallurgical Treatment to Sodium-Bonded Fuel

Electrometallurgical treatment, as described in the *Draft Environmental Impact Statement for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel* (DOE/EIS-0306D) (Draft EIS), can be used technically to treat sodium-bonded spent nuclear fuel, transforming it to a form for final disposal as waste. The technical demonstration of the processes and procedures will be completed in August 1999.

One of the technical problems posed by sodium-bonded spent nuclear fuel is the treatment of the large amount of sodium metal integral to the fuel. The primary purpose of including the sodium within the fuel is to increase the heat transfer between the fuel and the coolant during operations. This increased heat transfer permits the operation of the metal driver fuel into a high burnup regime despite significant swelling and damage to the structure of the heavy metal alloy in the fuel. While the inclusion of the sodium produces useful operational properties, it complicates spent nuclear fuel processing operations or preparation of the spent nuclear fuel for direct disposal since sodium metal is extremely reactive and is readily oxidized at low temperatures in an exothermic reaction. The safety concerns associated with disposing of chemically reactive amounts of sodium metal in the same package as spent nuclear fuel may preclude disposition of unprocessed sodium-bonded spent nuclear fuel in permanent repositories.

The EMT technique resolves the sodium-metal issue by dissolving the sodium (along with the other elements of the heavy metal alloy) in a lithium chloride - potassium chloride (LiCl-KCl) salt melt. This dissolution process is driven by an applied electrical potential. The high temperature of the salt melt promotes rapid reaction rates so that chemical equilibrium is quasi static under normal operating conditions. Chloride ion concentration is maintained in the vessel (by the addition of oxidizers such as depleted UCl_3 (uranium trichloride), which also downblends the highly enriched uranium (HEU)) at a level to ensure the oxidization of the sodium to sodium chloride (common table salt). Other elements (fission fragments) are also oxidized,

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[28] National Research Council. *An Assessment of Continued R&D into an Electrometallurgical Approach for Treating DOE Spent Nuclear Fuel*. 1995. Page 30.

[29] National Research Council. *An Evaluation of the Electrometallurgical Approach for Treatment of Excess Weapons Plutonium*. 1996. Page 27.

forming stable chlorides. Furthermore, iodine, a perennial problem in spent nuclear fuel dissolution, also forms a salt with sodium (NaI). In fact, the only volatile species in the molten-salt spent nuclear fuel mixture are noble gases such as krypton-85.

Electric current is applied to the salt melt by configuring the chopped spent nuclear fuel to act as the anode with a steel rod or plate serving as the cathode. Under design conditions, uranium chloride is reduced at the cathode surface, forming a dendritic metal deposit that is scraped off into a catch basket. This cathodic uranium reduction process accounts for the operation being referred to as uranium electrorefining. The partition of uranium metal on the solid cathode is highly favored thermodynamically and the product is fairly pure except for some mechanical inclusion of salts in the dendritic uranium structure. There are also trace amounts (parts per million) of neptunium and plutonium that are reduced on the cathode and codeposited there. This codeposition can be minimized by maintaining proper operating conditions. The electrorefining process recovers more than 95 percent of the spent nuclear fuel uranium mass. Nearly all the plutonium, the fission products, and the higher actinides are left in the salt melt, with a small portion of these materials and less than five percent of the uranium remaining undissolved in the cladding hulls.

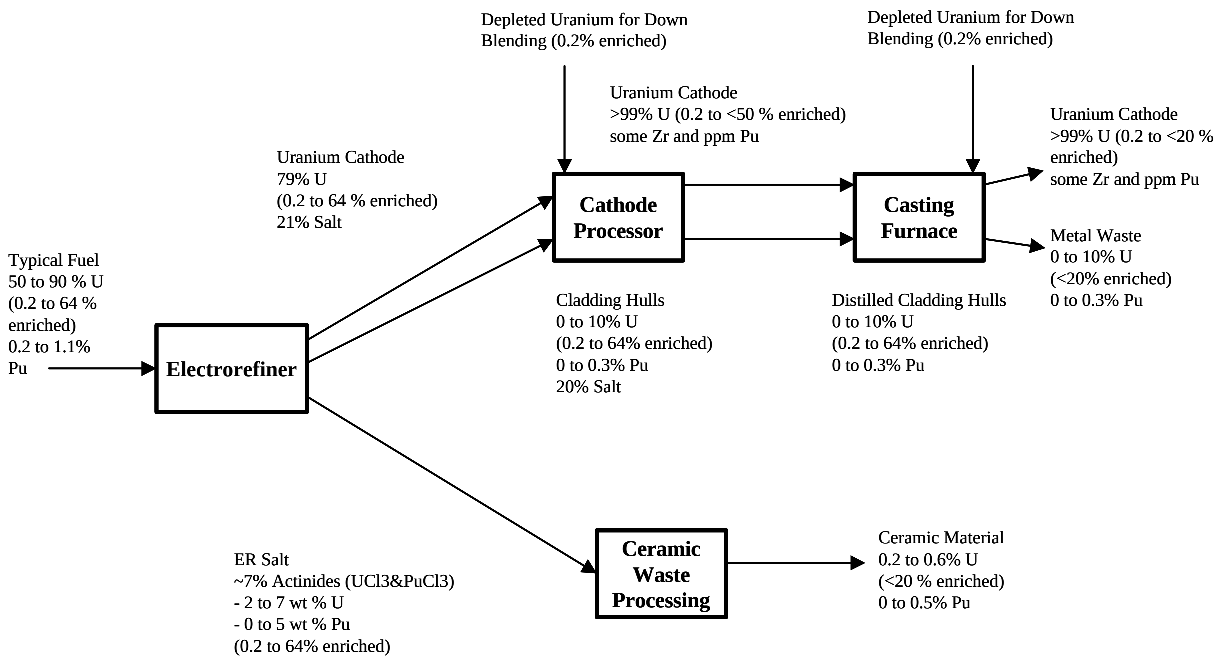
Since the electrorefiner is currently designed to operate in a batch mode, the refined uranium metal stream is removed periodically from the catch baskets and the electrorefiner is reloaded with chopped fuel. The recovered uranium metal is placed in a still that serves to distill away salt holdup. Salt distillation is followed by a casting operation producing a metal button of uranium that is better than 99 percent pure. During the casting operation, sufficient depleted uranium is added to reduce the overall enrichment of the uranium metal to below 20 percent uranium-235. The Draft EIS indicates that the low-enriched uranium would not be regarded as waste, and that uranium disposition decisions would be made under a separate process. Condensed salt from the distillation process is added to a salt high-level waste stream generated periodically when the salt melt becomes too contaminated for reuse. The undissolved empty stainless-steel hulls (cladding material) remaining at the anode are segregated from the salt and melted into a metal high-level waste button. A small fraction of the uranium (a few percent) and a much smaller amount of plutonium remains with the hulls and becomes part of this metal waste stream.

The same batch of salt is used over and over until it builds up a specified loading of waste products. The salt is then discharged as a high-level waste stream, and it is replaced with fresh, unloaded salt. The salt waste stream is processed by solidifying it, pulverizing it, and mechanically mixing it with zeolite and glass frit. It is then processed at a high temperature and pressed in a hot isostatic press to form a canned ceramic waste form containing a fraction of the uranium, nearly all of the plutonium, fission products, and actinides. When processing the driver fuel containing HEU (containing up to ~64 percent uranium-235), depleted uranium may be added to downblend the resulting uranium to below a 20 percent uranium-235 enrichment level. As a result, HEU is not included in either the metal or the salt waste stream. A simplified flow sheet of the EMT process is shown in Figure 3-1 giving approximate values for the fissile materials between each step of the process. Depleted uranium enrichment values reflect blanket fuel processing.

If EMT were used to process both driver and blanket fuel pins, the current schedule indicates that more than half of the 12-year program would be required to complete the remaining driver-pin processing even though there is 20 times more heavy metal contained in blanket pins. Logistics of handling fuel pins (driver pins are much smaller than blanket pins), controls on fissile material handling, and criticality issues drive the large disparity in mass throughput for the two fuel types.

It appears that, from a technical perspective, the current EMT process is adequately developed to convert the sodium-bonded spent nuclear fuel to a disposable form. However, the process is complicated, produces two major high-level waste streams and a third uranium metal stream, and requires specialized facilities and expertise.[30] Currently, these necessary technical resources are only available at ANL-W.

Figure 3-1. Electrometallurgical Process Flow Sheet



3.3 Technical Issues and Questions of Electrometallurgical Treatment Technology

3.3.1 CURRENT TECHNICAL STATUS OF ELECTROMETALLURGICAL TREATMENT FACILITIES AT ARGONNE NATIONAL LABORATORY-WEST

Electrometallurgical treatment is technically nearly ready to start production-level operations to convert the DOE sodium-bonded spent nuclear fuel inventory to recyclable uranium metal and a waste form intended to be acceptable for disposal in a geologic repository. Current operations have demonstrated the function of each part of the process, and final installation of salt waste disposition equipment in the Hot Fuel Examination Facility (HFEF) at ANL-W is currently underway. Remaining equipment that needs to be procured or fabricated to begin full-scale operations includes a full-scale isostatic press and casting equipment and special fixtures and tools to streamline operations in the remote processing environments. In addition, ANL-W needs to complete an environmental impact statement and record of decision, secure additional funding, and expand its labor force.

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[30] This process also produces transuranic and low-level wastes.

3.3.2 POTENTIAL OF ELECTROMETALLURGICAL TREATMENT TO SEPARATE PLUTONIUM FOR PRODUCTION OF NUCLEAR WEAPONS

Within the current equipment configuration and design at ANL-W, it is not possible to produce material that is directly usable for producing a plutonium-based explosive device by adjusting EMT operating parameters. Significant additional steps would be required to create a pathway (either in a covert or overt manner) to procure weapons-usable plutonium. However, if HEU-bearing spent nuclear fuel were processed, purified weapons-usable HEU metal could be produced.

Electrometallurgical treatment includes several unit processes that utilize technologies that are important for a pyroprocessing plant. This concept was explored in depth as part of the IFR program at ANL-W. The important technologies in question are electrorefiners (ERs), cathode processors (salt stills) and casting furnaces. The additional unit processes required to implement pyroprocessing include additional ERs with cadmium cathodes (either within current ERs or in separate ER units), and additional cathode processors for recovering cadmium (cadmium stills) and recovery of the plutonium-uranium alloy product. In addition to the unit processes described above, a host of supporting technologies, including heavy metal, salt, sodium and cadmium-handling equipment for processing feeds, extraction, stripping, and flow cleanups, would be required.

Pyroprocessing technology as envisioned in the IFR flowsheet is not capable of separating weapons-usable plutonium,[31] and separating such material was not an IFR program goal. The IFR program goal was to produce reactor fuel for liquid-metal reactors, which have much less constraining purity requirements than does material for weapons. The primary constituents that prevent the use of the IFR plutonium-uranium alloy product in weapons are the 70-percent uranium content (which would typically be LEU, natural uranium, or depleted uranium), which acts as a diluent, and the significant presence of both radioactive fission products and minor actinides.

Currently, nonaqueous processes are not sufficiently developed technically to perform the complete separations and product decontamination that would be required to produce weapons-usable plutonium from IFR plutonium-uranium alloys. Although fluoride volatility processes have been developed to separate and decontaminate plutonium, these processes are ineffective in separating plutonium when there are significant concentrations of transuranics in the feed stream (as would be the case when processing IFR alloys).[32] As a result, the only technically feasible approaches for separating and decontaminating IFR alloys would be the traditional aqueous processes such as coprecipitation (Bismuth Phosphate), solvent exchange (PUREX) or ion exchange. If separation steps such as these were added to the IFR process to treat the plutonium-uranium metal-alloy stream, a purified, weapons-grade plutonium stream could be produced. The isotopic distribution of the plutonium would be determined by the spent nuclear fuel used as the feed stock for the process (EBR-II driver and blanket fuel would both produce weapons-grade plutonium).

An approach for recovery of the EMT plutonium fraction exists apart from IFR pyroprocessing "add-backs" such as the cadmium cathode. This approach involves manipulation of discharged loaded ER salts. Uranium, plutonium, actinides and some other fission product metals can be reduced by addition of elemental

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[31] Goldman, D.L. (LLNL). *Some Implications of Using IFR High-Transuranic Plutonium ("HITRU PU") in a Proliferant Nuclear Weapon Program.* CODTU-94-0199. March 1994.

[32] Benedict, M., et. al., Nuclear Chemical Engineering, 2nd Edition, McGraw-Hill, 1981, pp. 462-466.

lithium to the loaded molten salt. Since lithium is more electropositive than either uranium or plutonium it would cause these metals to precipitate out and collect at the bottom of the reduction vessel. Following this step, the resulting metal alloy could be processed using traditional aqueous approaches to separate and decontaminate the plutonium.

Technical approaches to plutonium recovery from the EMT ceramic waste form have not been investigated in detail by DOE. The generation of sodalite or zeolite-A ceramic waste forms were previously investigated under the IFR program as a means to immobilize ER salt wastes containing significant quantities of fission products and very minute quantities of actinides.[33] [34] A fundamental change in the deployment of EMT, as related to this project, is the discarding of all of the actinides to the ceramic waste. Thus, controlled addition of more zeolite to the ER salt than was typical in the IFR process will be required to match the conditions of previous actinide concentrations in the ceramic waste form. Likewise, a sodalite form was chosen because of its chemical and radiation resistance resulting in a low leach rate for the fission products and actinides. With potentially higher concentrations of actinides in this waste form, the leachability of the actinides may be uncertain. A clear understanding of the leach rates of metals from the ceramic waste form into acid solutions is central to a technical evaluation of this plutonium diversion pathway if EMT were used for spent nuclear fuel treatment by a proliferant.

Based on the above analysis there are at least three places in the EMT flowsheet that are possible diversion points for plutonium:

- Spent nuclear fuel can be diverted from the feed stream of the EMT process directly into an aqueous process.

- Electrorefiner salts can be diverted to either an electrorefiner with a cadmium cathode (an IFR pyroprocessing "add-back") or to a reduction vessel. The resulting metal alloy could then be fed to an aqueous process.

- Ceramic waste can be pulverized and leached and plutonium could be separated (this process would require further research and development) and decontaminated using an aqueous process.

In each case, an aqueous process is required as a terminal step to obtain weapons-usable plutonium. Given that an aqueous process is the terminal step in each scenario, it is reasonable to conclude that aqueous process signatures would likely be key indicators of potential plutonium diversion from an EMT process.

[33] Lewis, M.A., et al. *Salt-Occluded Zeolites as an Immobilization Matrix for Chloride Waste Salt.* J. Am. Ceram. Soc., Vol. 76. 1993. Page 2826.

[34] Ackerman, J.P., et al. "Treatment of Wastes in the IFR Fuel Cycle." *Progress in Nuclear Energy.* Vol. 31, 1997. Page 141.

3.4 Application of Export Law and Nonproliferation Policy to Electrometallurgical Treatment

For purposes of export control, DOE treats EMT as one of a number of partitioning technologies for chemical processing of irradiated special nuclear material (SNM), whose export requires specific authorization by the Secretary of Energy under Section 810.8(c)(1) of DOE regulations in 10 CFR Part 810. Whether the Department, in consultation with other U.S. Government agencies, will regard EMT as a "reprocessing" technology is yet to be determined and probably will be decided on a case-by-case basis, depending on the application, whether the purpose is processing nuclear waste or separation of SNM, whether plutonium is subsequently separated, and similar factors.

Similarly, key elements of the hardware involved in EMT are subject to Nuclear Regulatory Commission and Department of Commerce export controls for nuclear nonproliferation purposes, based upon multilateral agreements with the Nuclear Suppliers Group and the Treaty on the Nonproliferation of Nuclear Weapons (NPT) Exporters Committee. Whether exports of the technology or hardware would be approved is largely a function of end use, to be decided on a case-by-case basis.

U.S. Support of International Fuel Cycle Technology

Under U.S. nonproliferation policy (see Appendix C) the United States does not encourage the civil use of plutonium and, accordingly, does not itself engage in plutonium reprocessing for either nuclear power or nuclear explosive purposes. In addition, the United States will encourage more restrictive regional arrangements to constrain fissile material production in regions of instability and high proliferation risk.

While the United States does not encourage plutonium reprocessing, there have been several cases where the United States has supported reprocessing in non-nuclear weapons states. One such historical example involves the Tokai-mura reprocessing plant in Japan in the 1970s. Although Japan is a non-nuclear weapons state, it was pursuing plutonium reprocessing for nuclear energy purposes. A U.S.-Japan nuclear cooperation agreement provided that the United States would make a safeguardability determination before any U.S.-origin spent nuclear fuel could be reprocessed. By the time the Tokai-mura reprocessing plant was completed in the mid-1970s, U.S. policy had shifted and did not allow the granting of a safeguardability determination.

U.S. and Japanese negotiators nevertheless developed an agreement that allowed the plant to operate. The terms of the agreement allowed the plant to reprocess up to 99 metric tons of U.S.-origin spent nuclear fuel at Tokai-mura on the condition that the plant not be operated as a commercial facility but rather be made available for research and development of reprocessing plant safeguards, including the installation, operation, and evaluation of sensors useful in tracking fissile material. In addition, the plant configuration allowed production of a uranium-plutonium mixture rather than a pure plutonium product and included a product monitoring stream.

3.5 Potential Use of Electrometallurgical Treatment in a Global Context

3.5.1 TECHNICAL AND POLICY FACTORS AFFECTING NONPROLIFERATION

The criteria applied in evaluating the global nonproliferation implications of EMT fall into two main categories: technical factors and policy factors. Technical factors are those related directly to the potential accessibility and attractiveness of the materials for use in nuclear weapons, both while they are being processed and in their final form. Policy factors are related to the effect U.S. decisions will have on current and future nuclear nonproliferation efforts.

3.5.1.1 Technical Factors

The three technical factors used in this assessment focus on assuring that nuclear material is not stolen by unauthorized parties or diverted to weapons use by the host state, both during and after treatment. For example, an alternative that involves many complex and difficult-to-measure bulk material processing steps could pose substantial difficulties in providing sufficient security and accounting to ensure and verify that no material is stolen. A disposition alternative that leaves the material in a form from which high-quality weapons material could be recovered relatively easily would do less to promote nonproliferation than alternatives that leave the materials in a form from which recovery is more difficult. The three technical factors include the degree to which a particular technology would:

(1) **Help assure that the weapons-usable nuclear material in the spent nuclear fuel could not be stolen or diverted during the process.** This includes an assessment of the attractiveness of the material to potential overt or covert theft with respect to its characteristics both during and after processing. In particular, this factor considers the type and concentration of fissile material, the total amount of fissile material, the concealability and transportability of discrete items containing fissile material, the security and remoteness of the material and facilities, and how easy it is to provide for a complete accounting of the material. Considerations in assessing the ease of material accountability are whether the involved facilities can be placed under international safeguards, whether the material is present in bulk form or as discrete items, and how complex are any processing steps. This factor also considers the radiation barriers present in the material in cases where the radiation barrier present during processing would be significantly different from that of the final forms. (The radiation barrier and other factors associated with the attractiveness of final forms are considered below.)

(2) **Facilitate cost-effective international monitoring.** This factor considers how easily international safeguards on the material and facilities can be implemented. This includes whether the facilities, if already existing, are designed and constructed in a manner to accommodate provisions for safeguarding and accountancy. Factors such as radiation and contamination that may prevent a design verification of a facility also are considered here. It also considers whether facility material accountancy is reasonably possible (*e.g.*, whether processing intricacies or potential material holdup within the facility would complicate a complete accounting of all fissile material in the feed).

(3) **Result in converting the spent nuclear fuel into a form from which retrieval of the material for weapons use would be difficult and unlikely.** This factor considers the radiation barrier and the chemical/physical form of the final forms produced by each technology or alternative. It considers whether the radiation barrier on the final forms is high enough to require remote handling and processing, and it considers the level of investment, time, and sophistication that would be required to extract fissile material from the form. For example, glass and ceramic forms would require more advanced processing than metal forms to extract fissile material. It also considers how easy it would be to detect such processing.

3.5.1.2 Policy Factors

The four policy factors used in this assessment focus on the ability of the United States to maintain and strengthen international efforts to stem the spread of nuclear arms, including the overall approach to limit the use of weapons-usable material in the civilian nuclear fuel cycle. For example, implementing an alternative that does not promote development of technologies that can be readily adapted to produce weapons-usable material would help reduce the risk associated with proliferation of weapons technologies. Additionally, U.S. decisions to choose a technology that could separate and recycle nuclear material (even if used only for waste management purposes) would offer additional arguments and justifications for advocates of the use of reprocessing and recycling technologies in other countries. Alternatively, by implementing stringent standards of security and accounting in its management of nuclear materials and spent nuclear fuel, the United States might be able to develop and demonstrate improved procedures and technologies for protecting and safeguarding that might be applied in other countries as well. This would reduce proliferation risks. The four policy factors include the degree to which a particular technology would:

(1) **Be consistent with U.S. policy related to reprocessing and nonproliferation.** This factor considers the U.S. policy articulated in President Clinton's September 27, 1993, press release concerning nonproliferation and export control (Appendix C). This factor considers whether the technology involves plutonium production, increases in the domestic plutonium stockpile, and operation of plutonium separation facilities.

(2) **Avoid encouraging other countries to engage in the reprocessing of spent nuclear fuel, or undermining U.S. efforts to limit the spread of reprocessing technology and activities, particularly to regions of proliferation concern.** This factor involves actions that strengthen other countries' arguments, leverage, or negotiating positions with respect to maintaining and increasing their programs for civilian plutonium separation and stockpiling.

(3) **Help demonstrate clearly that any treatment of these spent nuclear fuels will not represent the production by the United States of additional materials for use in nuclear weapons.** This factor considers whether the technology option involves fissile material processing in a manner in which separated weapons-usable special nuclear material is produced or current or former weapons production processes, facilities, or sites are used.

(4) **Support negotiation of a nondiscriminatory global fissile material cutoff treaty (FMCT),** including allowing for the possibility of verification approaches that would be acceptable to the United States. This factor considers whether the technology option includes plutonium separation, uranium enrichment, or purification of HEU, and if so, whether the facilities involved are technologically compatible with the application of international safeguards that would form the verification mechanism of an FMCT. It also considers the degree to which implementation of the technology under the specific proposed circumstances could affect the U.S. negotiation position for an FMCT.

Fissile Material Cutoff Treaty

On August 11, 1998, the 802nd plenary of the Conference on Disarmament (CD) agreed to establish an ad hoc committee to negotiate a ban on the production of fissile materials for weapons. The decision was based on a United Nations' resolution entitled "Prohibition of the production of fissile materials for nuclear weapons or other nuclear explosive devices," which was passed in December 1993.

Once approved by the CD's 61-member nations, the Fissile Material Cutoff Treaty (FMCT) will freeze the production of plutonium and highly enriched uranium (HEU) for nuclear weapons. FMCT negotiations promise to be long and difficult due to two key issues: (1) how to effectively verify the ban on fissile material for weapons, and (2) how to address existing stockpiles of unsafeguarded plutonium and HEU.

Each of the technical and policy factors must be weighed in judging the relative nonproliferation merits of each option. In many cases, actions can be taken to mitigate proliferation concerns, but the degree of certainty in the success of these actions varies widely.

3.5.2 NONPROLIFERATION EVALUATION OF ELECTROMETALLURGICAL TREATMENT IN A GLOBAL CONTEXT

This portion of the assessment discusses the overall nonproliferation concerns for EMT that should be considered in any reasonable scenario of EMT use. This includes both the current proposed action as well as any potential domestic or foreign application of the technology. The assessment evaluates EMT against the three technical factors and four policy factors identified in the previous section.

Assuring Against Theft or Diversion. Electrometallurgical treatment systems operate on a batch basis, which allows fundamentally easier material accounting than do continuous flow systems. The batch processing nature of EMT, combined with appropriate material sampling and physical security, can effectively assure against theft. These two factors also suggest that an EMT system under international safeguards can be equipped to effectively detect and deter diversion.

When processing HEU- or LEU-containing material, EMT systems produce material forms that are more attractive, from a theft and diversion perspective, than the feed material they receive. This factor is the root of one of the primary disadvantages of EMT from a nonproliferation perspective. However, EMT processing of unenriched or depleted uranium-containing material, which is unattractive material to begin with, provides no substantial increase in material attractiveness. As discussed below, EMT incorporates plutonium from spent nuclear fuel into a highly unattractive ceramic final form.

The primary concerns with respect to diversion occur in two scenarios: (1) where HEU-containing material is processed, or (2) where the EMT system is modified to serve as the initial processing steps of a hybrid plutonium separation process. As described in section 3.3.2, a modified EMT electrorefiner could serve as the initial processing step of several such potential system configurations. The primary role and advantage of the EMT electrorefiner in such a system would be to provide a compact process for removing uranium prior to further processing, thereby allowing a smaller and possibly more easily concealed plutonium purification process.

A discussion of the attractiveness of the EMT final forms for disposal is provided below.

International and DOE Safeguards

The International Atomic Energy Agency (IAEA) was established by a statute in 1957 as an independent organization in the United Nations family. Article III.A.5 of the Statute authorizes the IAEA "to establish and administer safeguards designed to ensure that special fissionable and other materials, services, equipment, facilities, and information made available to the Agency or at its request or under its supervision or control are not used in such a way as to further any military purpose; and to apply safeguards, at the request of the parties, to any bilateral or multilateral arrangement, or at any request of a State, to any of that State's activities in the field of atomic energy".

The IAEA is authorized under the 1968 Treaty on the Nonproliferation of Nuclear Weapons (NPT) to negotiate safeguards agreements with signatories to the NPT in order to independently verify nuclear activities. The purpose of international safeguards is to assure that the country is not diverting nuclear material nor has a clandestine nuclear weapons program. The United States, as a Nuclear Weapons State (NWS), has voluntarily offered to be subject to IAEA safeguards. Under other agreements (*e.g.*, the Trilateral Initiative, a Fissile Material Cutoff Treaty or a Russian bilateral agreement for the disposition of surplus weapons material), some U.S. facilities may also become subject to international verification and monitoring by the IAEA.

The safeguards system implemented by the IAEA includes three major components:

- Provide information, including design information and reporting by countries on facilities and all nuclear material under their control including uranium and plutonium;
- Containment and surveillance as complementary measures, such as seals and cameras, which contribute to conclusions that no material has been diverted; and
- On-site inspection by IAEA inspectors to independently verify material and activities.

The objective of a national safeguards system (*e.g.*, the system in the U.S. operated by DOE and NRC for government and commercial facilities respectively) is for the accounting and control of nuclear material to meet national objectives. This national system provides a basis for international assurances and ensures that facilities satisfy basic national requirements to protect material and facilities from theft and sabotage by unauthorized individuals and subnational groups. DOE requirements for nuclear material control and accountancy at DOE facilities focus on detection of material theft or loss at the subnational level.

Facilitating Cost-Effective International Monitoring. Full International Atomic Energy Agency (IAEA) safeguards have not been developed, implemented, or demonstrated on any EMT system, so it is not known how easily international safeguards could be implemented. Current approaches for material accounting would need to be adapted to the EMT system, or new approaches would need to be developed. Nevertheless, the batch-basis nature of EMT processing and the ability of an EMT system to be equipped with several material monitoring points, suggest that those factors would not serve as costly barriers to implementation of full international safeguards. In addition, design verification could be performed on any newly constructed EMT system to facilitate implementation of international safeguards.

The greatest concern with respect to this factor is the ability of international monitoring to detect and deter HEU recovery or system modifications that would allow the EMT electrorefiner to be modified and used as the initial process step of a hybrid plutonium separation and purification process.

Resulting in a Difficult-to-Retrieve Final Form. Electrometallurgical treatment produces two disposable final forms that contain fissile material: the ceramic form and the metal form. The ceramic form contains most of the plutonium processed in an EMT system, and this form has excellent resistence against fissile material retrieval for two reasons. First, highly complex processing would be required to extract plutonium from this form. Specific techniques for plutonium extraction from EMT ceramic forms have not been investigated in the United States, but at a minimum, the form would need to be pulverized, then subjected to the strongest possible acidic dissolution or leaching before any separation could be attempted. Second, most of the fission product radionuclides present in the spent nuclear fuel feed are retained in the ceramic form, thereby providing in many cases an effective radiation barrier necessitating remote processing. The metal form is somewhat less resistant to fissile material recovery, but still roughly equivalent to the initial spent nuclear fuel processed. It contains the undissolved residues of the original spent nuclear fuel being processed, including the metal fuel cladding, and any undissolved actinides (including plutonium), uranium, and fission products. Whether either the ceramic or metal forms meet the spent fuel standard would depend to a large degree on the burnup level and concentrations of plutonium and HEU fuel in the spent nuclear fuel being processed and the specific operating conditions of the EMT system. In general, the more attractive the spent nuclear fuel feed is, the more attractive the final forms will be. Lower burnup levels and higher fissile material concentrations in the spent nuclear fuel would tend to increase the attractiveness of the final forms, while the reverse would tend to decrease their attractiveness.

Maintaining Consistency with U.S. Nonproliferation Policy. One major issue with respect to consistency with nonproliferation policy is whether EMT should be classified as reprocessing. Because EMT is not capable of separating plutonium from fission products, it cannot be considered plutonium reprocessing. However, EMT does recover HEU from HEU-containing spent nuclear fuel, similar to other DOE reprocessing facilities such as the Idaho Chemical Processing Plant and the H-Canyon facility at the Savannah River Site (SRS), and for that reason, EMT could be recognized as a reprocessing technology. In addition, separation of weapons-usable plutonium is possible using a modified EMT electrorefiner in a hybrid system.

Because of the similarities between EMT and conventional reprocessing, in particular the ability of EMT to recover HEU and the role of the EMT electrorefiner in a potential hybrid plutonium recovery process, both domestic and export applications of EMT pose concerns with respect to U.S. nonproliferation policy.

In domestic applications of EMT, the most immediate policy issue involves the potential recovery of HEU. This issue can be effectively mitigated if the HEU were isotopically diluted to LEU. Longer-term policy issues relating to the domestic use of EMT involve the effect of U.S. support for the development of emerging technologies capable of separating or otherwise processing nuclear material. In nondomestic applications of EMT, considering EMT either a sensitive nuclear technology or a reprocessing technology would require case-specific restraints on exports of EMT technology in order to maintain consistency with U.S. nonproliferation policy. For exports, appropriate restraints on a case-specific basis should consider both the proposed purpose of the technology application (*e.g.*, HEU recovery, waste management, or health and safety) and the status of the applicant country (*e.g.*, if the country is a nuclear weapons state and U.S. ally or if the country already possesses a mature PUREX reprocessing capability).

Avoiding Encouragement of Plutonium Reprocessing. Electrometallurgical treatment technology originated as part of a breeder reactor development program, and some may view its continuation as sustaining the breeder fuel-cycle and reflecting a weakening in the U.S. view that breeding and recycling plutonium is not justified economically and raises serious proliferation risks. Electrometallurgical treatment has two clear links to conventional plutonium reprocessing that could result in encouraging countries to reprocess plutonium. First, EMT is an HEU-purification technology; second, EMT unit processes can be used in a hybrid plutonium production process. *Except in cases where EMT exhibits a decisive advantage (e.g., in security, cost, environmental, or health and safety) over other alternatives, the use, export, development, or promotion of this technology could cause countries to question the U.S. commitment against reprocessing. Closely scrutinizing proposals for applying EMT (and similar fissile material separations technologies) will help mitigate this issue.*

Building Confidence that the United States is Not Producing Materials for Weapons. In light of the current surplus of fissile material for the U.S. defense mission and the availability of other technologies and facilities in the United States to separate plutonium for weapons, near-term domestic applications of EMT that do not produce weapons-usable material would not be expected to call into question the U.S. policy against producing fissile material for the weapons program. The primary concern in this area is the lack of a strategy for future management of emerging technologies (*e.g.*, EMT) capable of separating or otherwise processing fissile material. As emerging technologies capable of producing (or being adapted to produce) weapons-usable material continue to be identified, their continued development is likely to call the U.S. policy into question unless the United States cautiously evaluates and appropriately restrains such technology development and use on a case-by-case basis.

Supporting Negotiation of a Verifiable and Nondiscriminatory FMCT. The primary issues pertaining to FMCT negotiations are the continued separation of plutonium, enrichment of uranium, and purification of HEU in support of nuclear weapons programs. Because EMT is an HEU-purification technology and EMT unit processes can be used in a hybrid plutonium production process, international monitoring of domestic U.S. EMT applications would presumably be required under an FMCT. In addition, case-by-case assessments of proposals for the use, export, development, or promotion of this technology are necessary to prevent the U.S. negotiating position of an FMCT from being undermined. Close control of management of EMT (and similar fissile materials separation technologies) would help mitigate this issue.

PART III: NONPROLIFERATION ASSESSMENT OF TECHNOLOGY OPTIONS AND ALTERNATIVES IN THE *DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE TREATMENT AND MANAGEMENT OF SODIUM-BONDED SPENT NUCLEAR FUEL*

Part III (Chapters 4 through 8) of this report provides a comparative assessment of all technology options and alternatives considered by the U.S. Department of Energy (DOE or the Department) in the *Draft Environmental Impact Statement for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel* (DOE/EIS-0306D) (Draft EIS). This includes electrometallurgical treatment as well as several other technologies and technology combinations.

- Chapter 4 describes the technical and policy factors relevant to U.S. nonproliferation efforts and this assessment.

- Chapter 5 presents a more detailed description of the technology options analyzed by the Department in the Draft EIS for treatment and management of sodium-bonded spent nuclear fuel.

- Chapter 6 presents a comparative assessment of the nonproliferation issues associated with each of the technology options.

- Chapter 7 presents a similar comparative assessment of the alternatives analyzed in the Draft EIS.

- Chapter 8 outlines the conclusions of this assessment, including identifying potential steps that could be taken to mitigate any nonproliferation disadvantages of the technologies.

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4.0 EXPLANATION OF NONPROLIFERATION POLICY FACTORS / FRAMEWORK

Each of the technology options for managing spent nuclear fuel has implications for nonproliferation efforts. The criteria applied in evaluating these implications fall into two main categories: technical factors and policy factors.[35] Technical factors are those related directly to the potential accessibility and attractiveness of the materials for use in nuclear weapons, both while they are being processed and in their final form. Policy factors are related to the effect U.S. decisions will have on its current and future nuclear nonproliferation efforts.

4.1 Technical Factors

The three technical factors used in this assessment focus on assuring that nuclear material is not stolen by unauthorized parties or diverted to weapons use by the host state, both during and after treatment. For example, an alternative that involves many complex and difficult-to-measure bulk material processing steps could pose substantial difficulties in providing sufficient security and accounting to ensure and verify that no material is stolen. A disposition alternative that leaves the material in a form from which high-quality weapons material could be recovered relatively easily would do less to promote nonproliferation than alternatives that leave the materials in a form from which recovery is more difficult. The three technical factors include the degree to which a particular technology would:

(1) **Help assure that the weapons-usable nuclear material in the spent nuclear fuel could not be stolen or diverted during the process.** This includes an assessment of the attractiveness of the material to potential overt or covert theft with respect to its characteristics both during and after processing. In particular, this factor considers the type and concentration of fissile material, the total amount of fissile material, the concealability and transportability of discrete items containing fissile material, the security and remoteness of the material and facilities, and how easy it is to provide for a complete accounting of the material. Considerations in assessing the ease of material accountability are whether the involved facilities can be placed under international safeguards, whether the material is present in bulk form or as discrete items, and how complex are any processing steps. This factor also considers the radiation barriers present in the material in cases where the radiation barrier present during processing would be significantly different from that of the final forms. (The radiation barrier and other factors associated with the attractiveness of final forms are considered below.)

(2) **Facilitate cost-effective international safeguards.** This factor considers how easily international safeguards on the material and facilities can be implemented. This includes whether the facilities, if already existing, are designed and constructed in a manner to accommodate provisions for safeguarding and accountancy. Factors such as radiation and contamination that may prevent a design verification of a facility also are considered here. It also considers whether facility material accountancy is reasonably possible (*e.g.*, whether processing intricacies or potential material holdup within the facility would complicate a complete accounting of all fissile material in the feed).

[35] The assessment factors discussed in this section are the same as those described in Section 3.5.1.

(3) **Result in converting the spent nuclear fuel into a form from which retrieval of the material for weapons use would be difficult and unlikely.** This factor considers the radiation barrier and the chemical/physical form of the final forms produced by each technology or alternative. It considers whether the radiation barrier on the final forms is high enough to require remote handling and processing, and it considers the level of investment, time, and sophistication that would be required to extract fissile material from the form. For example, glass and ceramic forms would require more advanced processing than metal forms to extract fissile material. It also considers how easy it would be to detect such processing.

4.2 Policy Factors

The four policy factors used in this assessment focus on the ability of the United States to maintain and strengthen international efforts to stem the spread of nuclear arms, including the overall approach to limit, restrict, and minimize the use of weapons-usable material in the civilian nuclear fuel cycle. For example, implementing an alternative that does not promote development of technologies that can be readily adapted to produce weapons-usable material would help reduce the risk associated with proliferation of weapons technologies. Additionally, U.S. decisions to choose a technology that could separate and recycle nuclear material (even if used only for waste management purposes) would offer additional arguments and justifications for advocates of the use of reprocessing and recycling technologies in other countries. Alternatively, by implementing stringent standards of security and accounting in its management of nuclear materials and spent nuclear fuel, the United States might be able to develop and demonstrate improved procedures and technologies for protecting and safeguarding that might be applied in other countries as well. This would reduce proliferation risks. The four policy factors include the degree to which a particular technology would:

(1) **Be consistent with U.S. policy related to reprocessing and nonproliferation.** This factor considers the U.S. policy articulated in President Clinton's September 27, 1993, press release concerning nonproliferation and export control (Appendix C). This factor considers whether the technology involves plutonium production, increases in the domestic plutonium stockpile, and operation of plutonium separation facilities.

(2) **Avoid encouraging other countries to engage in the reprocessing of spent nuclear fuel, or undermining U.S. efforts to limit the spread of reprocessing technology and activities, particularly to regions of proliferation concern.** This factor involves actions that strengthen other countries' arguments, leverage, or negotiating positions with respect to maintaining and increasing their programs for civilian plutonium separation and stockpiling.

(3) **Help demonstrate clearly that any treatment of these spent nuclear fuels will not represent the production by the United States of additional materials for use in nuclear weapons.** This factor considers whether the technology option involves fissile material processing in a manner in which separated weapons-usable special nuclear material is produced or current or former weapons production processes, facilities, or sites are used.

(4) **Support negotiation of a nondiscriminatory global fissile material cutoff treaty (FMCT),** including allowing for the possibility of verification approaches that would be acceptable to the United States. This factor considers whether the technology option includes plutonium separation, uranium enrichment, or purification of HEU, and if so, whether the facilities involved are technologically compatible with the application of international safeguards that would form the verification mechanism of an FMCT. It also considers the degree to which implementation of the technology under the specific proposed circumstances could affect the U.S. negotiation position for an FMCT.

Each of the technical and policy factors must be weighed in judging the relative nonproliferation merits of each option. In many cases, actions can be taken to mitigate proliferation concerns, but the degree of certainty in the success of these actions varies widely.

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5.0 DESCRIPTION OF TECHNOLOGIES

This chapter further describes the technology options the U.S. Department of Energy (DOE or the Department) is analyzing in detail in the *Draft Environmental Impact Statement for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel* (DOE/EIS-0306D) (Draft EIS) for managing sodium-bonded spent nuclear fuel.[36] Table 5-1 identifies the five technology options considered in this assessment.

Table 5-1. Five Technology Options Under Consideration

Technology Options [a]
Electrometallurgical Treatment (EMT)
Plutonium-Uranium Extraction (PUREX) Process
High-Integrity Cans
Melt and Dilute
No Action

[a] A sixth technology, declad and clean, is also included in the alternatives analyzed in the Draft EIS. In this assessment, it is considered in combination with other technologies. It is not considered separately in this assessment because it is always combined with other technologies in the alternatives analyzed in the Draft EIS.

5.1 Electrometallurgical Treatment

Electrometallurgical treatment (EMT) is a separations technology that converts spent nuclear fuel into three major streams, including ceramic and metal high-level waste forms and uranium metal ingots. This technology for sodium-bonded spent nuclear fuel was developed at Argonne National Laboratory-West (ANL-W) for processing Experimental Breeder Reactor-II (EBR-II) spent nuclear fuel and has been demonstrated for the stainless-steel clad, sodium-bonded, uranium-zirconium alloy fuel used in that reactor. This technology, without additional postprocessing techniques, does not produce separated plutonium. The Department is considering this technology option for both driver and blanket fuel. (One option analyzed in the Draft EIS involves treating both types of fuel using this technology. Four other options involve EMT of only driver fuel and the use of other technologies to treat or manage the blanket fuel.) Electrometallurgical treatment uses four principal unit processes–electrorefining, cathode processing, metal casting, and hot isostatic pressing–as well as some pre- and post-processing steps needed to prepare the fuel for treatment and to manage the wastes resulting from the unit processes.

The first step in processing is to disassemble the fuel assembly, separating the fuel assembly hardware from the fuel elements. The fuel elements (either driver or blanket elements) would then be placed into a cutting

[36] The Draft EIS considered seven processes for managing this spent nuclear fuel. DOE has dismissed from further consideration the three least technically mature of these processes. DOE concluded that the glass material oxidation and dissolution system process, the direct plasma arc-vitreous ceramic process, and the chloride volatility process are not reasonable alternatives for the Draft EIS because they all present substantial technical risks and would require too much development.

machine, chopped into short segments, and placed in stainless-steel baskets to form an anode of the electrorefiner. Each cathode of the electrorefiner would consist of a bare steel surface, where uranium metal would be collected.

The electrorefiner would operate at 500°C (932°F) and contain a molten eutectic mixture of two salts, lithium chloride and potassium chloride (LiCl and KCl). Natural or depleted uranium trichloride (UCl_3) would be added as an oxidizer to facilitate the electrofining process. The chopped fuel elements in the anode baskets would be lowered into the molten salt. When an electric current is applied between the anodes and cathodes, the uranium, plutonium, and other transuranic elements, most of the fission products, and the bond sodium would dissolve into the salt. The electric current would cause the uranium to be deposited on the steel cathode. The cladding hulls and some of the uranium, plutonium, actinides, and insoluble fission products (*i.e.*, noble metals), would remain undissolved in the anode basket throughout this process.

After a majority of the uranium is deposited on the cathode, the salt, containing the sodium, transuranic elements (including plutonium), and most fission products, would be solidified, ground to a desired size, and mixed with zeolite. Zeolite is any of a network of aluminum oxide and silicon oxide used as a filter and ion-exchange agent. The salt would be absorbed into the lattice of the zeolite, forming a dry particulate solid. Glass powder would be added to the zeolite mixture and hot pressed to produce a ceramic high-level waste form that could be suitable for ultimate disposal in a geologic repository.

In the cathode processing step, the uranium that was deposited on the cathode would be removed and treated to evaporate any adhered salts. In the final metal casting step, the uranium would then be melted, and depleted uranium would be added if necessary to reduce the enrichment level below 20 percent uranium-235. The molten uranium would be solidified to form low-enriched uranium ingots, which DOE would retain in controlled storage until a decision is made on their final disposition.

The cladding hulls and the insoluble fission products remaining in the anode basket would be melted in a casting furnace to produce a metal high-level waste form for disposal in a geologic repository. In the interim the waste would be stored at the Radioactive Scrap and Waste Facility.

The Draft EIS projects that, if selected, the EMT of the 60 metric tons (MT) of driver and blanket fuel (Draft EIS Alternative 1) could begin in 2000 and be completed within approximately 13 years. EMT processing driver fuel alone (3.5 MT, Draft EIS Alternatives 2, 3, 4, and 5) would require approximately 7 years.

5.2 Plutonium-Uranium Extraction (PUREX) Process

This technology option is a separations technology that converts spent nuclear fuel to uranium trioxide, plutonium metal, and high-level waste. The PUREX process is a counter-current solvent extraction method used to separate and purify uranium and plutonium from fission product-containing spent nuclear fuel. It is only being considered for processing sodium-bonded blanket assemblies.

The Department's F-Canyon facility at the Savannah River Site (SRS) has used the PUREX process for aluminum-clad fuel and targets. Use of the facility at SRS involves certain restrictions due to the design of the facility: 1) the presence of sodium is incompatible with the aqueous nitric acid solutions used in the process, and 2) the presence of stainless-steel cladding would require significant modifications or additions to the existing head-end of the facility. Because of these restrictions, the existing SRS facility could be used to process blanket fuel only if the fuel were first pre-processed by disassembly and hardware removal, decladding, and sodium removal. In such a case, the pre-processing would be conducted at ANL-W and the F-Canyon facility would be used for PUREX processing. The presence of zirconium and the difficulties involved in separating sodium from the driver fuel pins preclude the use of the existing PUREX facility at SRS for treating driver assemblies. Because extensive modifications to the SRS facility would be required to allow PUREX treatment of driver fuel, such treatment is not being considered in the Draft EIS.

Reprocessing Facilities at Savannah River Site

Two reprocessing facilities capable of separating fissile material are located at the Savannah River Site, H-Canyon and F-Canyon. Constructed in the early 1950s, these facilities initially operated to produce fissile material for national defense purposes. Their operation stopped in the early 1990s as a result of safety concerns and reduced need for nuclear-weapons materials. Both facilities have been restarted in recent years to process fissile materials to produce more stable forms suitable for long-term storage, reuse, or disposal. The materials being processed for this purpose include actinide targets; HEU fuel; laboratory solutions; sand, slag, and crucible (containing minute quantities of plutonium); and actinide solutions. Under U.S. policy, the plutonium produced from these activities would not be used in weapons. The schedule for processing materials for which decisions have been made ends in 2003.

The PUREX process has several steps: dissolution, head end, first cycle, second uranium cycle, and second plutonium cycle. The fuel declad and cleaned blanket elements would be dissolved in an aqueous solution of nitric acid, resulting in a solution containing depleted uranium, plutonium, and fission products. Next the solution would be transferred to a centrifuge, where the silica and other impurities would be removed as waste. The clarified solution would proceed to the first cycle, which would have two functions. It would remove fission products and other chemical impurities using a liquid-liquid solvent extraction process and it would separate the solution into two product streams (*i.e.*, uranium and plutonium) for further processing. The separation process occurs as the product solution passes through centrifugal contactor and mixer-settler banks.

Four streams would be produced from the first-cycle: a plutonium-containing solution, a uranium-containing solution, a solvent stream, and an aqueous high-level waste stream containing the bulk of the fission products. The uranium-containing solution would be sent to the second uranium cycle where it is further purified and converted to uranium nitrate (which can be subsequently converted to uranium oxide in separate processes). The plutonium containing solution would be sent to the second plutonium cycle where it is further purified and converted to plutonium nitrate (which can be subsequently converted to plutonium metal or oxide in separate processes). PUREX processing of the blanket assemblies would be expected to produce 257 kilograms of plutonium metal (of which 250 kilograms would arise from processing of EBR-II blanket fuel and 7 kilograms from the Fermi-1 blanket fuel), which would be managed in accordance with decisions reached under the *Surplus Plutonium Disposition Environmental Impact Statement* (DOE/EIS-0282). The aqueous high-level waste would be eventually processed to a borosilicate glass form, and the solvent stream would be recycled back to the process.

The Draft EIS projects that, if selected, PUREX processing the 57 MT of blanket fuel (under Draft EIS Alternative 3) could begin in 2005 and be completed in less than one year. The decladding and sodium removal activities performed on blanket fuel at ANL-W could begin in 2003.

5.3 High-Integrity Cans

This is a packaging technology in which spent nuclear fuel would be packaged in cans constructed of a highly corrosion-resistant material (such as Hastelloy C-22) to provide long-term corrosion protection in a repository environment. The high-integrity can provides substitute cladding for damaged or declad fuel, or another level or containment for intact fuel. The can could be used to store fuel onsite until it is ready to be shipped to a repository. Prior to shipment to a repository, the high-integrity cans are placed into standardized stainless-steel canisters ready for disposal in waste packages. Prior to packaging, reactive sodium, if present, may be removed from the fuel.

This option is being considered for only sodium-bonded blanket assemblies. Each canister can hold 60 kilograms of spent nuclear fuel, or roughly 1.3 EBR-II blanket assemblies. Prior to packaging, the fuel would be pre-processed by disassembly and hardware removal, decladding, sodium removal, and vacuum drying. Vacuum drying is performed to remove free water that could contribute to continued corrosion of the fuel elements and to the buildup of hydrogen gas generated by radiolytic decomposition of the water and by metal corrosion. All pre-processing and packaging activities would be conducted at ANL-W. The pre-processed blanket fuel would be packaged in high-integrity cans, which would be placed in dry storage at an appropriate location. Eventually, the cans would be placed in a geologic repository.

Because the metallic sodium must be removed from the fuel before packaging, and sodium removal is not practical for driver fuel, this option is viable only for blanket fuel. The Draft EIS projects that, if selected, packaging the 57 MT of blanket fuel (under Draft EIS Alternative 2) could begin in 2003 and be completed within approximately 7 years.

5.4 Melt and Dilute

Three different options are being considered for the melt and dilute technology option (Table 5-2). These options involve treatment of either all sodium-bonded fuel or only blanket fuel and, depending on the alternative, they can be performed at either ANL-W or SRS. This technology is not a separations technology and does not produce separated highly enriched uranium (HEU) or plutonium. The melt and dilute process is a simpler technology than many others, especially for metal fuels, although the presence of sodium is an additional complication. Melt and dilute processes would require further research and development before they can be implemented. With this process, most of the fission products would remain in the final form, but some would be volatilized.

Table 5-2. Melt and Dilute Technology Options and EIS Alternatives

Melt and Dilute Option (Corresponding Draft EIS Alternative)	Fuel Treated and Location
Option 1 (Alternative 5)	Blanket at SRS
Option 2 (Alternative 4)	Blanket at ANL-W
Option 3 (Alternative 6)	Blanket at ANL-W Driver at ANL-W

ANL-W = Argonne National Laboratory-West
SRS = Savannah River Site

Under Option 1, blanket fuel assemblies would be pre-processed into bare uranium fuel pins by disassembly, decladding, and sodium removal at ANL-W. Melt and dilute processing would be conducted at the SRS Transfer, Storage, and Treatment Facility in L Area. The bare uranium fuel pins then would be melted in an induction-heated melter at a temperature of 1,000°C (1,832°F). Alloying metals and neutron poisons would be added to the melt as necessary. No isotopic dilution of uranium would be required because the uranium in the blanket fuel is already diluted. This option would produce 200-kilogram alloy ingots containing about 60 kilograms of fuel and 140 kilograms of aluminum. Under this option (under Draft EIS Alternative 5), melt and dilute processing of blanket fuel at SRS could begin in 2020 and would last approximately three years.

Under Option 2, blanket fuel assemblies would be preprocessed at ANL-W by disassembly and cutting the ends off of each fuel element. However, the fuel would not be declad. Melt and dilute processing under this option also would be conducted at ANL-W. The preprocessed blanket fuel would be placed in an induction heated melter, where it would be gradually heated to separate the remaining sodium by melting (at 200°C, 392°F) and volatilization (at 500°C, 932°F). The remaining blanket fuel with cladding would be further heated to 1,400°C (2,552°F) at which point it would melt and be mixed with additional iron. No isotopic dilution of uranium would be required because the uranium in the blanket fuel is not enriched. This option would produce 100-kilogram alloy ingots containing about 50 percent fuel and 50 percent steel. Under this option (under Draft EIS Alternative 4), melt and dilute processing of blanket fuel at ANL-W could begin in 2005 and be completed in approximately 7 years.

Option 3 would be used to process driver fuel still containing the cladding and some metallic sodium. Pre-processing and processing both would be performed at ANL-W. The driver fuel would be pre-processed by chopping, and the chopped driver fuel would be loaded into an induction furnace and covered with a layer of low melting temperature salt containing uranium, iron, or manganese chloride as a component to oxidize the molten sodium. The molten salt would capture sodium vapors escaping from the fuel elements as they melted. The furnace would be operated at 1,400°C (2,552°F). Depleted uranium would be added in a ratio of about 2.5-to-1 to reduce the enrichment to less than 20 percent uranium-235. Steel would also be added to the molten mixture. The salt, containing some fission products and the sodium, would be stabilized in a ceramic form. The uranium, actinides, and most fission products would remain in the metal melt and would be cast into 100-kilogram ingots containing 50 percent fuel and 50 percent steel. They would contain a higher proportion of fission products than the corresponding blanket fuel ingots. Under this option (under Draft EIS Alternative 6), melt and dilute processing of driver fuel could begin in 2005 and melt dilute processing of all fuel would last approximately 10 years.

For each of these options, an off-gas system would capture the volatile and semi-volatile fission products for stabilization and processing into waste forms suitable for disposal. The ingots would be loaded into baskets and the baskets would be placed in canisters. The canisters would be evacuated, filled with inert gas, sealed, and transferred to storage where they would await shipment to a geologic repository.

Using the melt and dilute process to treat spent nuclear fuel containing metallic sodium (Options 2 and 3) would necessitate an inert atmosphere to avoid a reaction between metallic sodium and moisture in the air. Both the Fuel Conditioning Facility (FCF) and Hot Fuel Examination Facility (HFEF) at ANL-W have inerted cells and could be used to install a melt and dilute process. In this case, the melt and dilute process could also be used to treat sodium-bonded blanket and driver fuel (Options 2 and 3). Building 105-L at SRS has been proposed to be used for installing a melt and dilute process to treat SRS spent nuclear fuel, but the proposed process does not have an inerted cell. It would only be used for the sodium-bonded blanket fuel after decladding and removal of the metallic sodium (Option 1).

5.5 No Action

Under this option, the sodium-bonded spent nuclear fuel would not be treated (no sodium would be removed) except for stabilization activities that may be necessary to prevent potential degradation of some of the spent nuclear fuel. Spent nuclear fuel storage would continue at the Idaho National Engineering and Environmental Laboratory (INEEL) and ANL-W wet and dry storage facilities. Small quantities of sodium-bonded spent nuclear fuel located at other sites would continue to be transferred to INEEL and ANL-W facilities in accordance with the Record of Decision for the *Department of Energy's Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Final Environmental Impact Statement* (DOE/EIS-0203-F) or other existing site-specific National Environmental Policy Act (NEPA) documentation. As an option under this alternative, DOE would actively research and develop less mature technologies (*e.g.,* glass material oxidation and dissolution system process and the direct plasma arc-vitreous ceramic process). Also, the direct disposal of untreated blanket and driver sodium-bonded spent nuclear fuel using high-integrity cans would be considered.

5.6 Special Safety and Health Considerations

The Department has not identified any near-term health and safety issues requiring the proposed action. However, some of the storage containers of EBR-II spent nuclear fuel in the Idaho Nuclear Technology and Engineering Center CPP-603 storage pool have been observed to be leaking, and the EBR-II fuel inside has reacted with the water and produced hydrogen gas. This is one of the reasons DOE is planning to remove all the spent nuclear fuel from the CPP-603 storage pool and place it in dry storage within the next five years. NEPA coverage for this activity is provided by the Department of Energy's *Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Final Environmental Impact Statement* (DOE/EIS-0203-F).

6.0 EVALUATION OF TECHNOLOGIES IN THE U.S. CONTEXT AS SCOPED IN THE *DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE TREATMENT AND MANAGEMENT OF SODIUM-BONDED SPENT NUCLEAR FUEL*

This section evaluates the specific technology options the U.S. Department of Energy (DOE or the Department) is considering in the *Draft Environmental Impact Statement for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel* (DOE/EIS-0306D) (Draft EIS) for the treatment and management of sodium-bonded spent nuclear fuel against each of the technical and policy factors described in Chapter 4. These factors are the same as those used in the global assessment of EMT presented in Chapter 3.

While this assessment in Chapter 6.0 is intended to address the specific applications of each *technology option*, it is nonetheless a simplified high-level analysis. The high-level nature of this assessment is consistent with the currently limited available knowledge about the specific implementation details of each technology option. At this point in the planning process, such details, some of which may ultimately become significant in either compounding or mitigating the issues identified in this assessment, cannot yet be determined.

The technical factors used in this analysis include assuring against theft or diversion, facilitating cost-effective international monitoring, and resulting in a difficult-to-retrieve form.

The policy factors used in this analysis include maintaining consistency with U.S. nonproliferation policy, avoiding encouragement of plutonium reprocessing, building confidence that the United States is not producing material for weapons, and supporting negotiation of a verifiable and nondiscriminatory fissile material cutoff treaty (FMCT). Figure 6-1 summarizes the findings regarding the nonproliferation impacts of each technology option. The remainder of this chapter details these findings.

Figure 6-1. Technology Options as Presented in the Draft EIS Rated Against Criteria

		Electrometallurgical Treatment	Plutonium-Uranium Extraction (PUREX) Process and Disposition	High-Integrity Cans	Melt and Dilute	No Action
Technical Factors	Assuring Against Theft or Diversion	◑	◑	●	◑	●
	Facilitating Cost-Effective International Monitoring	◑	◑	●	◑	●
	Difficult-to-Retrieve Final Form	●	○ [a]	◑	◑	● [b]
Policy Factors	Consistency with Nonproliferation Policy	●	◑	●	●	●
	Avoiding Encouragement of Plutonium Reprocessing	◑	○	●	●	●
	Building Confidence that the United States is Not Producing Materials for Weapons	●	◑	●	●	●
	Supporting Negotiation of an FMCT	◑	◑	●	●	●

● Fully meets nonproliferation objectives
◑ Could raise nonproliferation concerns
○ Raises nonproliferation concerns

[a] Under this option, plutonium would be separated and added to the surplus plutonium stockpile which is already planned to be dispositioned into either reactor fuel or a stabilized final waste form. This rating considers the nonproliferation concerns of the interim form of separated plutonium.
[b] Under this option, the end-of-process form may or may not be further treated to produce a final form for repository disposal. This rating considers the nonproliferation concerns of the untreated end-of-process form.

6.1 Electrometallurgical Treatment

This option involves a separations technology that produces separated highly enriched uranium (HEU) as an intermediate product, and several final products including a recyclable separated low-enriched uranium (LEU) product, a plutonium-containing ceramic high-level waste form, and a high-level metal waste form.

6.1.1 TECHNICAL FACTORS (Electrometallurgical Treatment)

Assuring Against Theft or Diversion. The electrometallurgical treatment (EMT) option involves both complex bulk processing of the nuclear material and separation of fissile material. These factors make implementation of international safeguards more difficult. While international safeguards concepts have been developed for this process, they have not been demonstrated in detail, and there is little experience with these international safeguards to date. Because it involves separating HEU (which is subsequently diluted to LEU as proposed in the Draft EIS) from the fission products, it creates, albeit temporarily, weapons-usable nuclear materials. Applying DOE material control and physical protection procedures at the facilities where the material is managed would reduce the risk of theft to a low level. Theft would be adequately deterred by continuing to implement the Department's Level 3 safeguards and protections, as required under DOE Order 5633.3b, to the existing EMT operation, including accounting and physical security measures. The United States has already placed the Argonne National Laboratory-West (ANL-W) facilities on a list of eligible facilities as part of a voluntary offer for international safeguards to the International Atomic Energy Agency (IAEA).[37] Concurrent with any application of IAEA safeguards, DOE materials control and accountability procedures also will continue to apply to the facility. ◑ *Involves bulk processing and separation of fissile material.*

Description and Nonproliferation Impacts of Technology Features

Technology Feature	Description	Nonproliferation Impact
Bulk Processing	Processing that involves handling nuclear materials in bulk form, such as in chopped pieces, powders, solutions, and molten liquids, rather than handling individual items.	Because bulk material measurement technologies are imperfect, it is difficult to assure that the quantity of nuclear material present after the bulk processing step is exactly equal to the amount present before the step.
Separations	In the context of sodium-bonded spent nuclear fuel, separations technologies (*e.g.*, PUREX and electrometallurgical treatment) extract uranium (or plutonium) from spent fuel.	Separating fissile materials from fission products takes away the self protection provided by the highly-radioactive fission products. Also, separation may reduce the number of steps necessary to make the nuclear materials weapons usable, thereby making it more attractive for weapons use.
New System	Systems that are yet to be completely designed and constructed out of new equipment and components and which may be installed in either new or existing facilities.	New systems are easier to monitor than are old systems because new systems can be designed to facilitate international verification.

Facilitating Cost-Effective International Monitoring. Because EMT of HEU-containing fuel elements involves bulk processing and separation of HEU, international monitoring would presumably be required for the facility under a fissile material cutoff treaty (FMCT). However, safeguards concepts for EMT have not been demonstrated in detail. Establishing effective international monitoring should be possible for a reasonable cost. ◑ *Safeguards not yet demonstrated.*

Resulting in a Difficult-to-Retrieve Final Form. The final forms resulting from EMT of HEU- and plutonium-containing spent nuclear fuel include separated low-enriched and depleted uranium metal suitable for recycling, a ceramic high-level waste form containing low-enriched or depleted uranium (up to 0.6 percent uranium with a uranium-235 enrichment level of up to 12 percent), plutonium (up to 0.7 percent), and fission products, intended to be suitable for geologic disposal, and a metal high-level waste form containing up to 14 percent uranium (with a uranium-235 enrichment level of up to 12 percent), up to 0.1 percent plutonium, noble metal fission products, and nonradioactive metal elements, also intended to be suitable for geologic disposal. All three of these forms require significant processing to produce weapons-usable material, including chemically separating the plutonium and chemically separating and enriching the uranium. The radiation levels of the two high-level waste forms vary over a broad range depending on which spent fuel items they originate from. At the high end of this range, some ceramic forms derived from driver fuel may be above 100 rem/hour at 1 meter and may offer

[37] The IAEA has chosen not to place the ANL-W facilities under international safeguards.

an effective deterrent to theft. At the low end, ceramic forms derived from Fermi-1 blanket fuel are about 0.1 mrem/hour, offering no effective deterrent to retrieval. Forms derived from the EBR-II driver and blanket fuel are projected to exhibit radiation barriers of roughly 60 and 4 rem/hour, respectively. Potentially combining waste from high and low radiation spent nuclear fuel into a common form or spiking the waste with highly radioactive fission products from other sources could produce more proliferation-resistant waste forms by eliminating ceramic forms with low radiation barriers. However, no decision has yet been made on combining driver and blanket waste, and there is currently no plan to perform fission product spiking of the waste. ● *High-level of difficulty in separation of fissile material from final forms.*

6.1.2 POLICY FACTORS (Electrometallurgical Treatment)

Maintaining Consistency with U.S. Nonproliferation Policy. Because this technology does not separate plutonium for potential reuse, this technology is consistent with U.S. policy on plutonium reprocessing and the use of plutonium. ●

Avoiding Encouragement of Plutonium Reprocessing. This option involves an emerging separations technology that, while technically not considered reprocessing, is, in some respects, analogous to reprocessing. The similarities between EMT and conventional reprocessing would have somewhat greater potential to encourage reprocessing in other countries than would the high-integrity cans or melt and dilute options. This potential stems primarily from its ability to produce weapons-usable HEU and the historical origins of EMT as part of the IFR breeder fuel-cycle technology, which can be perceived as having several parallels to the PUREX technology used worldwide to process spent nuclear fuel. Extending the time that U.S. separations facilities operate and using a separations process to prepare spent nuclear fuel for geologic disposal (while at the same time acknowledging that the fuel does not pose near-term safety and health vulnerabilities and that such processing technically is not required) could serve to undermine U.S. credibility in expressing concern to other countries about the proliferation problems associated with conventional reprocessing in the nuclear fuel cycle. To mitigate this impact, the United States would want to make very clear three substantial differences between this action and conventional reprocessing of commercial power-reactor spent nuclear fuel. First, under this action, no actual plutonium separations capability would be developed and no actual plutonium separations would occur, while substantial technological development and processing modifications would need to be completed to provide a plutonium separations capability. Second, this action is being performed to address unique chemical reactivity requirements of a highly unusual type of spent nuclear fuel. Third, this action is being performed to prepare the fuel for disposal rather than as part of a breeder fuel cycle. ◑ *Process separates HEU and utilizes a closed fuel-cycle technology.*

Building Confidence that the United States is Not Producing Material for Weapons. Since this approach would involve bulk processing and separation of HEU (which would be immediately blended to LEU), it would have the potential to raise concerns that material was being produced for weapons unless international monitoring were put in place to confirm that this was not the case. However, even without international monitoring, this concern can be effectively mitigated by placement of the ANL-W facilities on the list of eligible facilities list as part of a voluntary offer for international safeguards to the IAEA. ●

Supporting Negotiation of a Verifiable and Nondiscriminatory FMCT. Since EMT could be used to separate HEU, and could be modified to separate plutonium, these processes would presumably require verification once an FMCT was in place to ensure that no HEU or plutonium was being produced for weapons. Although safeguards concepts that could be used for such verification have been developed, they have not been demonstrated, and an additional demonstration program would be needed to prepare for fissile cutoff implementation if this technology were chosen. *System for verification needs to be developed and implemented.*

6.2 Plutonium-Uranium Extraction (PUREX) Process

This option involves a separations technology that produces separated plutonium, depleted uranium oxide, and a vitrified high-level waste form containing fission products in canisters of borosilicate glass. This technology is only being considered for blanket assemblies. This approach would involve active operation of a former weapons production facility capable of separating plutonium and would involve bulk processing of plutonium.

6.2.1 TECHNICAL FACTORS (PUREX Process)

Assuring Against Theft or Diversion. The PUREX process option would involve bulk processing of plutonium-containing blanket assemblies and is expected to produce an estimated 257 kilograms of separated plutonium. The bulk processing would involve some of the accounting uncertainties associated with safeguarding reprocessing plants. However, DOE material control and physical protection procedures would reduce the risk of theft to a low level. *Involves bulk processing and separation of fissile material.*

Facilitating Cost-Effective International Monitoring. International monitoring of the F-Canyon facility would presumably be required under an FMCT. Implementation of international monitoring would be more difficult and costly under the PUREX option than under the other options. Several factors contribute to the difficulty and additional cost. First, the facility at SRS was not designed or constructed with IAEA safeguards in mind, and the types and locations of monitoring that can be conducted are limited. Second, existing contamination in the facility further limits the monitoring options. Third, existing contamination prevents conducting a design verification. Measuring the fissile content in the materials before and after processing would offer a potential alternative. However, this alternative presents a risk in that significant measurement differences may occur due to measurement uncertainty or potential holdup of fissile material in the processing equipment. *System for verification needs to be developed and implemented.*

Resulting in a Difficult-to-Retrieve Final Form. The final forms resulting from PUREX processing of blanket fuels include separated plutonium metal, depleted uranium oxide, and a vitrified glass form containing fission products. The latter two forms would not contain appreciable fissile material and do not pose a proliferation concern. The separated plutonium metal would result in a net increase in the stockpile of weapons-usable plutonium. However, the plutonium would be considered surplus and would be managed with other surplus weapons-usable plutonium. *Final form is weapons-usable plutonium.*

6.2.2 POLICY FACTORS (PUREX Process)

Maintaining Consistency with U.S. Nonproliferation Policy. This option is somewhat inconsistent with U.S. policy with respect to plutonium reprocessing. This option would increase the U.S. stockpile of weapons-usable plutonium.

Avoiding Encouragement of Plutonium Reprocessing. This option would have more potential to encourage reprocessing in other countries than any of the other options because it would extend the time that U.S. reprocessing facilities operate, potentially undermining the credibility of U.S. policy which is not to encourage plutonium reprocessing. To mitigate this impact, the United States would want to make very clear that this action is substantially different from reprocessing commercial power-reactor spent nuclear fuel because it is being performed to prepare the fuel for disposal rather than as part of a closed fuel cycle. ○

Building Confidence that the United States is Not Producing Material for Weapons. This approach has the potential to raise concerns that material was being produced for weapons unless international monitoring was put in place to confirm that this is not the case. ◑ *System for verification needs to be developed and implemented.*

Supporting Negotiation of a Verifiable and Nondiscriminatory FMCT. Since this approach would involve processing plutonium in a former weapons production facility capable of separating plutonium, this option could affect negotiation of an FMCT. In addition, the potential closure and need for international monitoring of these facilities may be identified in the future as negotiating issues for an FMCT. ◑ *System for verification needs to be developed and implemented.*

6.3 High-Integrity Cans

This option does not involve bulk processing of fissile material, and does not produce separated HEU or plutonium as an intermediate or final product. It involves repackaging metal-based, plutonium-containing spent nuclear fuel. This technology is only being considered for blanket assemblies.

6.3.1 TECHNICAL FACTORS (High-Integrity Cans)

Assuring Against Theft or Diversion. Under this option, the Department could adequately protect against theft by continuing to apply the Department's Level 3 safeguards and protections as required under DOE Order 5633.3b to the facilities where the fuel would be managed, including accounting and physical security measures. This technology option involves only mechanical handling of nuclear material and does not involve bulk processing, reducing the likelihood of an undetected theft. The United States has already placed the ANL-W facilities on a list of eligible facilities as part of a voluntary offer for international safeguards to the IAEA. ●

Facilitating Cost-Effective International Monitoring. Since little processing would be involved, international monitoring and safeguarding of this approach, if desired, should be straightforward and low-cost. International inspectors could confirm canister loading and sealing, and individual cans could be tagged, sealed, and checked periodically until the fuel is eventually loaded in disposal containers. ●

Resulting in a Difficult-to-Retrieve Final Form. Of the two types of blanket fuel that would be managed under this option, EBR-II blanket fuel and Fermi-1 blanket fuel, the greatest concern lies with the EBR-II fuel. The 22 metric tons heavy metal (MTHM) of EBR-II blanket fuel contains 250 kilograms of plutonium at an average concentration of slightly more than 1 percent. In contrast, the 34 MTHM of Fermi-1 blanket fuel contains 7 kilograms of plutonium at an average concentration of about 0.02 percent. Neither of these fuels exhibits a radiation barrier adequate to provide an effective deterrent to retrieval. For a typical assembly of EBR-II blanket fuel, the radiation barrier is 4 rem/hour at 1 meter; for Fermi-1 blanket fuel, the radiation barrier is 0.04 rem/hour at 1 meter. However, chemical separation would be required to retrieve the contained plutonium from the final forms. Potentially placing highly radioactive fission products from other sources inside the cans could produce more proliferation-resistant waste forms by eliminating cans with low radiation barriers. However, there is currently no plan to add fission products to the cans. ◑ *Low radiation barrier; plutonium can be retrieved from final form using PUREX.*

6.3.2 POLICY FACTORS (High-Integrity Cans)

Maintaining Consistency with U.S. Nonproliferation Policy. This approach involves no separation of weapons-usable material and would be fully consistent with and supportive of U.S. nonproliferation policies relating to reprocessing and the nuclear fuel cycle. ●

Avoiding Encouragement of Plutonium Reprocessing. Since no reprocessing would be involved, this approach would avoid any possible encouragement of foreign reprocessing activities. Technical work done on disposal issues and standards could be used by other countries to encourage disposal in cans such as the high-integrity cans. ●

Building Confidence that the United States is Not Producing Material for Weapons. Since this approach does not involve the use of a separations technology or facility, it would be clear that no material is being recovered for a weapons program. ●

Supporting Negotiation of a Verifiable and Nondiscriminatory FMCT. Since this approach does not include plutonium separation, uranium enrichment, or purification of highly enriched uranium, this option should not raise any difficulties or issues for negotiation of an FMCT. ●

6.4 Melt and Dilute

This option produces a plutonium- and uranium-containing final product. This technology is being considered for both blanket and driver assemblies. The Department is committed to the use and development of melt and dilute technology to treat other DOE spent nuclear fuels, in particular the highly-enriched, aluminum-based research reactor fuels to be managed at SRS. This technology option is being considered by the Department for use in three of the alternatives analyzed in the Draft EIS (Table 5-2).

6.4.1 TECHNICAL FACTORS (Melt and Dilute)

Assuring Against Theft or Diversion. The melt and dilute option involves bulk processing, with the associated accounting uncertainties. There is limited experience safeguarding such molten blending operations, so existing safeguarding approaches would have to be modified to effectively safeguard material being processed. Under this option, the Department could adequately protect against theft by continuing to apply the Department's Level 3 safeguards and protections as required under DOE Order 5633.3b to the facilities where the fuel would be managed, including accounting and physical security measures. The United States has already placed the ANL-W facilities on a list of eligible facilities as part of a voluntary offer for international safeguards to the IAEA. ◑ *Involves bulk processing.*

Facilitating Cost-Effective International Monitoring. Because this option would involve bulk processing, international monitoring (comparable to IAEA safeguards) of the process, if desired, would likely be more costly and intrusive than in the high-integrity cans option. Costs would be reduced and effectiveness increased by the fact that the approach would be carried out in a newly-built melt and dilute system, allowing for full design verification as well as for provisions for the application of international safeguards to be integrated into the design of the equipment from the outset. Because the material would be batch processed, measuring the fissile content in the material before and after processing would offer a potential alternative. ◑ *System for verification needs to be developed and implemented.*

Resulting in a Difficult-to-Retrieve Final Form. Using this technology option, a single final form would be produced containing plutonium, low-enriched or depleted uranium, and fission products. The Department has not estimated the strength of the radiation barrier in this final form. However, assuming that the radiation barrier of the waste form is approximately equal to that of the unprocessed spent nuclear fuel, final forms resulting from blanket fuel processing (the radiation barrier on a blanket fuel assembly is up to 4 rem/hour) would not exhibit an effective deterrent to retrieval. However, the radiation barrier of the final forms resulting from driver fuel processing (or a combination of driver and blanket fuel) would be higher (at least 54 rem/hour for a single driver assembly) and would provide a modest deterrent to retrieval. Similarly, the plutonium content and uranium enrichment level for the final forms will vary depending on whether the form is derived from driver assemblies, blanket assemblies, or a combination of the two, and the amount of dilution that occurs through addition of depleted uranium. (In the proposed alternative that includes melt and dilute processing of both blanket and driver fuel, the Department plans to process each fuel type separately. However, further research and development in this technology conceivably may allow for co-processing of driver and blanket assemblies.) In all variations of the final form, the uranium and plutonium would require significant processing to become weapons-usable material, including physical processing, several chemical conversions, chemical separation of the plutonium or uranium, and re-enrichment of the uranium. Potentially combining waste from high and low radiation spent nuclear fuel into a common form or spiking the waste with highly radioactive fission products from other sources could produce more proliferation-resistant waste forms by eliminating final forms with low radiation barriers. However, no decision has yet been made on combining driver and blanket waste, and there is currently no plan to perform fission product spiking of the waste. ◑ *Low radiation barrier; plutonium can be retrieved from final form using PUREX.*

6.4.2 POLICY FACTORS (Melt and Dilute)

Maintaining Consistency with U.S. Nonproliferation Policy. This approach involves no separation of weapons-usable material and would be fully consistent with and supportive of U.S. nonproliferation policies relating to reprocessing and the nuclear fuel cycle. ●

Avoiding Encouragement of Plutonium Reprocessing. This approach does not involve separation of fissile material and would not be likely to encourage reprocessing in other countries. ●

Building Confidence that the United States is Not Producing Material for Weapons. Since this approach does not involve the use of a separations technology or facility, it would be clear that no material is being recovered for a weapons program. Conducting this activity at ANL-W rather than at SRS would avoid processing materials in facilities collocated with operating former weapons production facilities and would facilitate international monitoring. ●

Supporting Negotiation of a Verifiable and Nondiscriminatory FMCT. Since this approach does not include plutonium separation, uranium enrichment, or purification of HEU, this option should not raise any difficulties or issues for negotiation of an FMCT. ●

6.5 No Action

This option involves the continued storage of sodium-based fuel at ANL-W and Idaho National Engineering and Environmental Laboratory (INEEL) facilities, continued research and development of treatment and management technologies, and deferral of disposition decisions. Because the fuel is required to be removed from the State of Idaho by 2035 in accordance with the Department's existing agreement with the State, any deferred actions would nevertheless need to meet this requirement. *The assessment of this option only considers the management of fuel during the continued interim storage period prior to deferred treatment.* As an option under this alternative, DOE would actively research less mature technologies (*e.g.*, glass material oxidation and dissolution system process and the direct plasma arc-vitreous ceramic process). Further, this alternative considers direct disposal of untreated blanket and driver sodium-bonded spent nuclear fuel using high-integrity cans.

6.5.1 TECHNICAL FACTORS (No Action)

Assuring Against Theft or Diversion. Assuring against theft or diversion under this option would be similar to that using high-integrity cans, with some distinct differences. This option is similar to others in that the Department could adequately assure against theft by continuing to apply the Department's Level 3 safeguards and protections as required under DOE Order 5633.3b to the facilities where the fuel would be managed, including accounting and physical security measures. This technology option involves only limited mechanical handling of nuclear material and does not involve bulk processing, simplifying material accountancy. The United States has already placed the ANL-W facilities on a list of eligible facilities as part of a voluntary offer for international safeguards to the IAEA. This option would offer a marginally greater assurance against theft than the high-integrity can option due to the presence of reactive sodium, which complicates fuel handling, and the reduced material handling in the near term. ● *Presence of sodium complicates recovery process.*

Facilitating Cost-Effective International Monitoring. Since no processing would be involved, international monitoring and safeguarding of this approach, if desired, should be straightforward and low-cost. ●

Resulting in a Difficult-to-Retrieve Final Form. Although this option does not produce final forms for disposal, it does result in continued potential long-term storage and maintenance of the existing spent nuclear fuel forms.[38] Although nearly all of the fuel is metal based from which fissile material could be recovered using conventional chemical separations, the presence of sodium on the fuel would complicate at least the initial steps of any recovery process. The radiation barrier exhibited by much of the fuel is too low to offer an effective deterrent to retrieval. The fuels with the greatest concern are the 22 MTHM of EBR-II blanket fuel, which contains roughly 1 percent plutonium and exhibits a radiation barrier of 4 rem/hour at 1 meter, and some of the unirradiatied Fast Flux Test Facility (FFTF) plutonium/uranium and uranium fuels (~0.1 MTHM). Of considerably lesser concern is the 34 MTHM of Fermi-1 blanket fuel, which contains 7 kilograms of plutonium (an average concentration of about 0.02 percent) and exhibits a radiation field of 0.1 millirem/hour at 1 meter, and the highly radioactive driver fuels, which exhibit radiation barriers of between 50 and 400 rem/hour at 1 meter. Potentially combining high and low radiation spent nuclear fuel inside the

[38] A possible secondary benefit from delay is the allowance for waste acceptance criteria to be promulgated before a final waste form is developed.

same storage container or placing highly radioactive fission products from other sources inside the containers could produce more proliferation-resistant waste forms by eliminating containers with low radiation barriers. However, no decision has yet been made on combining driver and blanket fuel in the same containers, and there is currently no plan to perform fission product spiking of the waste. ● *Presence of sodium complicates recovery process.*

6.5.2 POLICY FACTORS (No Action)

Maintaining Consistency with U.S. Nonproliferation Policy. This approach involves no separation of weapons-usable material and would be fully consistent with and supportive of U.S. nonproliferation policies relating to reprocessing and the nuclear fuel cycle. ●

Avoiding Encouragement of Plutonium Reprocessing. Since no reprocessing would be involved, this approach would avoid any possible encouragement of foreign reprocessing activities. ●

Building Confidence that the United States is Not Producing Material for Weapons. Since this approach does not involve the use of a separations technology or facility, it would be clear that no material is being recovered for a weapons program. ●

Supporting Negotiation of a Verifiable and Nondiscriminatory FMCT. Since this approach does not include plutonium separation, uranium enrichment, or purification of highly enriched uranium, this option should not raise any difficulties or issues for negotiation of an FMCT. ●

7.0 EVALUATION OF THE *DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE TREATMENT AND MANAGEMENT OF SODIUM-BONDED SPENT NUCLEAR FUEL* ALTERNATIVES

This section evaluates each of the alternatives the U.S. Department of Energy (DOE or the Department) is currently considering in detail for treatment and management of sodium-bonded spent nuclear fuel. It combines the concerns identified in the global assessment of electrometallurgical treatment (EMT) presented in Chapter 3 with the assessment of all technology options being considered in the *Draft Environmental Impact Statement for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel* (DOE/EIS-0306D) (Draft EIS). Table 7-1 presents the seven alternatives being considered in the Draft EIS in terms of the technologies, type of spent nuclear fuel, and location of treatment. This assessment of alternatives only evaluates the fuel and technology combinations comprising the proposed alternatives.[39] Figure 7-1 summarizes the findings regarding the nonproliferation impacts of each alternative.

Table 7-1. Proposed Alternatives and Technology Options

Technology		Alternatives						
		1	2	3	4	5	6	No Action
EMT at ANL-W		D & B	D	D	D	D		
PUREX at SRS				B				
High-Integrity Cans at ANL-W			B					
Melt and Dilute	SRS					B		
	ANL-W				B		D & B	
No Action								D & B

EMT = Electrometallurgical Treatment
ANL-W = Argonne National Laboratory-West
PUREX = Plutonium-Uranium Extraction Process
SRS = Savannah River Site
D refers to the driver sodium-bonded spent nuclear fuel.
B refers to the blanket sodium-bonded spent nuclear fuel.

The factors upon which this assessment is based are the same seven technical and policy factors used in the global EMT assessment (Section 3.5.2) and the Draft EIS technology options assessment (Chapter 6). While this assessment is intended to address the specific actions under each alternative, it is nonetheless a simplified high-level analysis. The high-level nature of this assessment is consistent with the currently limited available knowledge about the specific implementation details of each technology option. At this point in the planning process, such details, some of which may ultimately become significant in either compounding or mitigating the issues identified in this assessment, have not yet been determined.

[39] Excluded from the assessment are (1) technology and fuel combinations not among the Draft EIS alternatives (*e.g.*, PUREX treatment of driver fuel) and (2) technologies not identified among the Draft EIS alternatives (*e.g.*, glass material oxidation and dissolution system process and plasma arc treatment).

Figure 7-1. Draft EIS Alternatives Ratings Against Criteria

		Alternatives						
		1 (EMT @ ANL-W)	2 (EMT & HICs @ ANL-W)	3 (EMT @ ANL-W & PUREX @ SRS)	4 (EMT & M&D @ ANL-W)	5 (EMT @ ANL-W & M&D @ SRS)	6 (M&D @ ANL-W)	No Action
Technical Factors	Assuring Against Theft or Diversion	◑	◑	◑	◑	◑	◑	●
	Facilitating Cost-Effective International Monitoring	◑	◑	○	◑	◑	◑	●
	Difficult-to-Retrieve Final Form	●	◑	○[a]	◑	◑	◑	●
Policy Factors	Consistency with Nonproliferation Policy	●	●	○	●	●	●	●
	Avoiding Encouragement of Plutonium Reprocessing	◑	●	○	●	●	●	●
	Building Confidence that the United States is Not Producing Materials for Weapons	●	●	◑	●	●	●	●
	Supporting Negotiation of an FMCT	◑	◑	◑	◑	◑	●	●

● Fully meets nonproliferation objectives
◑ Could raise nonproliferation concerns
○ Raises nonproliferation concerns

[a] Under this option, the plutonium would be separated and added to the surplus plutonium stockpile.
ANL-W = Argonne National Laboratory-West
EMT = Electrometallurgical Treatment
HIC = High-Integrity Can
M & D = Melt and Dilute
PUREX = Plutonium-Uranium Extraction Process
SRS = Savannah River Site

7.1 Alternative 1: Electrometallurgical Treatment of All Fuel at Argonne National Laboratory-West

The primary advantage of this alternative is that the ceramic final form is more resistant to plutonium recovery than metal forms that result under other alternatives using melt and dilute and high-integrity cans. The primary disadvantages of this alternative, and all alternatives that involve EMT of driver fuel, stems from the fact that EMT involves bulk processing of fissile material and produces separated highly enriched uranium (HEU) as an interim product. However, this is mitigated by the fact that the HEU is downblended to low-enriched uranium (LEU). These disadvantages are compounded by the fact that approaches for international monitoring have not yet been developed for EMT. Additionally, continued development and promotion of a breeder fuel-cycle technology capable of separating HEU from spent nuclear fuel and being adapted to separate plutonium could be viewed as an effort to keep breeder fuel-cycle technology alive and reflect a weakening in the U.S. view that breeding and recycling plutonium is not justified and raises proliferation risks.

7.2 Alternative 2: Electrometallurgical Treatment of Driver Fuel at Argonne National Laboratory-West, High-Integrity Can Packaging of Blanket Fuel at Argonne National Laboratory-West

This alternative presents all the same advantages and disadvantages as Alternative 1. The advantage includes the difficulty in retrieving plutonium from the EMT final forms. The disadvantages involve the interim separation of HEU, the use of bulk processing, the expected difficulties involving implementation of international monitoring of EMT, and the possible perception of a weakening in U.S. nonproliferation policy that may result from use of EMT.

However, some of the disadvantages are marginally mitigated by several factors. First, international monitoring would be easier to implement for the blanket fuel managed using high-integrity cans because this fuel can be accounted for as discrete items rather than measurement. Second, avoiding bulk processing of blanket fuel would also make theft of material easier to detect. Third, while bulk processing is generally considered a disadvantage, it is unlikely that bulk processing of driver fuel can be avoided due to the internally trapped sodium so that, in comparison to other alternatives, this factor is not a disadvantage. Another advantage of this alternative is that it distinguishes between the various fuel types and recognizes that advanced fuel processing is only required on a subset of the Department's sodium-bonded spent nuclear fuel inventory. By avoiding separations processing for waste management except in cases where it presents clear advantages in other areas (*e.g.*, cost, technological availability, health and safety risk), the Department would signal the U.S. commitment against unnecessary use of spent nuclear fuel separations technologies wherever practical, thereby avoiding encouraging other countries to adopt or continue plutonium processing. The primary disadvantage of this alternative is that plutonium recovery from the cleaned and packaged blanket fuel would require less complex processing than recovery from comparable EMT ceramic waste forms.

7.3 Alternative 3: Electrometallurgical Treatment of Driver Fuel at Argonne National Laboratory-West; Declad and Clean Blanket Fuel at Argonne National Laboratory, PUREX at the Savannah River Site

This alternative presents all the same advantages and disadvantages as Alternative 1. The advantage includes the difficulty in retrieving plutonium from the EMT final forms. The disadvantages involve the interim separation of HEU, the unnecessary use of bulk processing to manage blanket fuel, the expected difficulties involving implementation of international monitoring of EMT, and the possible perception of a weakening in U.S. nonproliferation policy that may result from use of EMT.

In addition to the advantages and disadvantages cited above, this alternative exhibits four more disadvantages. First, an increased nonproliferation risk results from potential loss of material during transport of blanket fuel between Argonne National Laboratory-West (ANL-W) and the Savannah River Site (SRS). Second, implementation of international monitoring would be more difficult at the SRS PUREX facility. Third, this alternative produces separated plutonium, the least desirable final form with respect to nonproliferation. Fourth, this alternative includes plutonium separation and extending operation of a former weapons production facility capable of separating plutonium, either of which might by viewed as a weakening in the U.S. opposition to plutonium reprocessing.

7.4 Alternative 4: Electrometallurgical Treatment of Driver Fuel at Argonne National Laboratory-West, Melt and Dilute Blanket Fuel at Argonne National Laboratory-West

This alternative presents all the same advantages and disadvantages as Alternative 1. The advantage includes the difficulty in retrieving plutonium from the EMT final forms. The disadvantages involve the interim separation of HEU, the unnecessary use of bulk processing to manage blanket fuel, the expected difficulties involving implementation of international monitoring of EMT, and the possible perception of a weakening in U.S. nonproliferation policy that may result from use of EMT.

Another advantage of this alternative is that it distinguishes between the various fuel types and recognizes that advanced fuel processing involving separations is only required on a subset of the Department's sodium-bonded spent nuclear fuel inventory. By avoiding separations processing for waste management except in cases where it presents clear advantages in other areas (*e.g.*, cost, technological availability, health and safety risk), the Department would signal the U.S. commitment against use of separations technologies wherever practical, thereby avoiding encouraging other countries to adopt or continue plutonium processing. Another advantage is that the melt and dilute facility at ANL-W would be newly constructed and uncontaminated and would presumably be more amenable to design verification than an existing facility. Additional disadvantages of this alternative are that the metal forms resulting from melt and dilute processing of blanket fuel are less resistant to plutonium recovery than comparable ceramic final forms produced from EMT of blanket fuel under Alternative 1.

7.5 Alternative 5: Electrometallurgical Treatment of Driver Fuel at Argonne National Laboratory-West; Declad and Clean Blanket Fuel at Argonne National Laboratory-West, Melt and Dilute at the Savannah River Site

This alternative exhibits the same advantages and disadvantages as Alternative 4. The advantages include the difficulty in retrieving plutonium from the EMT final forms, an avoidance of separations processing except in cases where it exhibits a decisive advantage, and the higher likelihood of being able to easily perform a design verification of the melt and dilute processing facility. The disadvantages include the interim separation of HEU, the unnecessary use of bulk processing to manage blanket fuel, the expected difficulties involving implementation of international monitoring of EMT, the possible perception of a weakening in U.S. nonproliferation policy, and the production of metal final forms from the melt and dilute process that are less resistant to plutonium recovery than comparable ceramic final forms produced from EMT.

An additional disadvantage under this alternative is an increased nonproliferation risk from potential loss of material during transport of blanket fuel between ANL-W and SRS.

7.6 Alternative 6: Melt and Dilute All Fuel at Argonne National Laboratory-West

The advantages and disadvantages of this alternative are similar to those involving melt and dilute processing in Alternative 4, but it does not exhibit some of the disadvantages associated with EMT. The advantages of this alternative include an avoidance of separations processing, and the higher likelihood of being able to easily perform a design verification of the melt and dilute processing facility. The disadvantages include the unnecessary use of bulk processing to manage blanket fuel, the expected difficulties involving implementation of international monitoring of melt and dilute, and the production of metal final forms from the melt and dilute process that are less resistant to plutonium recovery than comparable ceramic final forms produced from EMT.

7.7 No Action Alternative

This alternative exhibits several marginal, but not decisive, advantages over the other alternatives. First, the alternative does not involve bulk processing of fissile material (an advantage over all alternatives). Second, this alternative does not involve separation of HEU or plutonium (an advantage over alternatives using EMT and PUREX). Third, the final form, which would contain reactive sodium metal, would be difficult to process to recover fissile material (an advantage over all alternatives except Alternative 1). Fourth, this alternative does not involve transportation (an advantage over alternatives using PUREX and melt and dilute at SRS). In addition, this alternative would provide an opportunity for additional technology development of less mature technologies and would allow evolution of waste acceptance criteria. The primary disadvantage of this alternative is that it does not convert the spent nuclear fuel into a final form that will be acceptable to disposal in a geologic repository with a high degree of confidence. Another key disadvantage of this alternative (though not a disadvantage from a nonproliferation standpoint) is that the Department could lose some of its functional expertise and corporate experience in the specialized EMT technology at ANL-W, which would hamper consideration and increase the cost of implementing the EMT technology in the future.

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8.0 CONCLUSIONS

Of the seven alternatives proposed in the *Draft Environmental Impact Statement for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel* (DOE/EIS-0306D) (Draft EIS), only one–that involving Plutonium-Uranium Extraction (PUREX) reprocessing at the Savannah River Site (SRS)–raises significant nonproliferation issues. All other alternatives, which include either electrometallurgical treatment, melt and dilute processing, canning, continued storage and deferred treatment, or combinations of these technology options, either fully meet U.S. nonproliferation objectives or have the potential to raise only limited concerns. The Office of Arms Control and Nonproliferation supports implementation of any of the remaining six non-PUREX alternatives. Some of the remaining six alternatives have marginal, but not decisive, advantages over others, but all are acceptable in terms of nonproliferation risk. Among these alternatives, the primary concern lies not with the specific actions proposed in the Draft EIS but with subsequent actions that may involve EMT. Specifically, as emerging technologies, such as EMT, capable of producing (or being adapted to produce) weapons-usable material continue to be identified, their continued use, export, development, and promotion could cause countries to question the U.S. commitment against reprocessing and provide encouragement for the expansion or initiation of reprocessing programs in other countries.

In summary:

- All alternatives could be implemented with a reasonable assurance against theft or diversion of weapons-usable materials.

- All alternatives could be made subject to international monitoring. However, international monitoring would be more difficult to implement at the SRS F-Canyon facility than at the other facilities.

- Except for plutonium metal produced from PUREX reprocessing all final forms exhibit properties that would make retrieval of weapons-usable material reasonably difficult. However, for all alternatives, the radiation barrier associated with final forms is much lower than that exhibited from commercial spent nuclear fuel.

- Spiking final forms with fission products from other sources, though not currently planned, could effectively increase the radiation barrier of the final forms and decrease their attractiveness for theft.

- Only one alternative–that involving PUREX reprocessing at SRS–results in an increase in weapons-usable fissile material inventories. However, the newly produced material would be managed with other surplus plutonium and would not become part of the domestic nuclear weapons inventory.

- All but one alternative–the one involving PUREX reprocessing at SRS–are fully consistent with U.S. policy with respect to reprocessing and nonproliferation.

- The alternatives including no action, canning, melt and dilute processing, and limited EMT (driver fuel only) provide no encouragement to other countries to engage in civilian or military plutonium reprocessing. In comparison, the alternatives involving PUREX reprocessing and broad application of EMT (*i.e.*, EMT of both driver and blanket fuel) have a greater potential to provide encouragement to countries to engage in plutonium reprocessing. Given the quantity and unique characteristics of the fuel and the reason for the treatment, however, such encouragement, if any, would be limited.

- All but one alternative–the one involving PUREX reprocessing at SRS–would build confidence that the United States is not producing materials for weapons. While it is generally recognized that the United States is no longer producing materials for weapons, the alternative involving PUREX reprocessing at SRS involves operation of a former weapons production facility and production of weapons-usable material.

- All alternatives would support negotiation of a Fissile Material Cutoff Treaty (FMCT), which would probably require some form of international monitoring at facilities capable of producing separated plutonium or highly enriched uranium. However, international monitoring would be more difficult to implement at the SRS F-Canyon facilities.

- Future actions involving technologies capable of producing (or being adapted to produce) weapons-usable material should be closely scrutinized to evaluate their consistency with their individual and cumulative impact on U.S. policy concerning reprocessing and nonproliferation.

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APPENDIX B ACRONYMS

ANL-W	Argonne National Laboratory-West
DOE	United States Department of Energy
EMT	Electrometallurgical Treatment
ER	electrorefiner
FCF	Fuel Conditioning Facility
FFTF	Fast Flux Test Facility
FMCT	fissile material cutoff treaty
HEU	highly enriched uranium
HFEF	Hot Fuel Examination Facility
HIC	High-Integrity Can
IAEA	International Atomic Energy Agency
IFR	Integral Fast Reactor
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
LEU	low-enriched uranium
NEPA	National Environmental Policy Act
NPT	Treaty on the Nonproliferation of Nuclear Weapons
NSG	Nuclear Suppliers Group
PUREX	Plutonium-Uranium Extraction
SNT	sensitive nuclear technology
SRS	Savannah River Site

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APPENDIX C NONPROLIFERATION AND EXPORT CONTROL POLICY STATEMENT

THE WHITE HOUSE

Office of the Press Secretary

For Immediate Release September 27, 1993

FACT SHEET
NONPROLIFERATION AND EXPORT CONTROL POLICY

The President today established a framework for U.S. efforts to prevent the proliferation of weapons of mass destruction and the missiles that deliver them. He outlined three major principles to guide our nonproliferation and export control policy:

-- Our national security requires us to accord higher priority to nonproliferation, and to make it an integral element of our relations with other countries.

-- To strengthen U.S. economic growth, democratization abroad and international stability, we actively seek expanded trade and technology exchange with nations, including former adversaries, that abide by global nonproliferation norms.

-- We need to build a new consensus — embracing the Executive and Legislative branches, industry and public, and friends abroad — to promote effective nonproliferation efforts and integrate our nonproliferation and economic goals.

The President reaffirmed U.S. support for a strong, effective nonproliferation regime that enjoys broad multilateral support and employs all of the means at our disposal to advance our objectives.

Key elements of the policy follow.

<u>Fissile Material</u>

The U.S. will undertake a comprehensive approach to the growing accumulation of fissile material from dismantled nuclear weapons and within civil nuclear programs. Under this approach, the U.S. will:

-- Seek to eliminate where possible the accumulation of stockpiles of highly-enriched uranium or plutonium, and to ensure that where these materials already exist they are subject to the highest standards of safety, security, and international accountability.

-- Propose a multilateral convention prohibiting the production of highly-enriched uranium or plutonium for nuclear explosives purposes or outside of international safeguards.

-- Encourage more restrictive regional arrangements to constrain fissile material production in regions of instability and high proliferation risk.

-- Submit U.S. fissile material no longer needed for our deterrent to inspection by the International Atomic Energy Agency.

-- Pursue the purchase of highly-enriched uranium from the former Soviet Union and other countries and its conversion to peaceful use as reactor fuel.

-- Explore means to limit the stockpiling of plutonium from civil nuclear programs, and seek to minimize the civil use of highly-enriched uranium.

-- Initiate a comprehensive review of long-term options for plutonium disposition, taking into account technical, nonproliferation, environmental, budgetary and economic considerations. Russia and other nations with relevant interests and experience will be invited to participate in this study.

The United States does not encourage the civil use of plutonium and, accordingly, does not itself engage in plutonium reprocessing for either nuclear power or nuclear explosive purposes. The United States, however, will maintain its existing commitments regarding the use of plutonium in civil nuclear programs in Western Europe and Japan.

Export Controls

To be truly effective, export controls should be applied uniformly by all suppliers. The United States will harmonize domestic and multilateral controls to the greatest extent possible. At the same time, the need to lead the international community or overriding national security or foreign policy interests may justify unilateral export controls in specific cases. We will review our unilateral dual-use export controls and policies, and eliminate them unless such controls are essential to national security and foreign policy interests.

We will streamline the implementation of U.S. nonproliferation export controls. Our system must be more responsive and efficient, and not inhibit legitimate exports that play a key role in American economic strength while preventing exports that would make a material contribution to the proliferation of weapons of mass destruction and the missiles that deliver them.

Nuclear Proliferation

The U.S. will make every effort to secure the indefinite extension of the Non-Proliferation Treaty in 1995. We will seek to ensure that the International Atomic Energy Agency has the resources needed to implement its vital safeguards responsibilities, and will work to strengthen the IAEA's ability to detect clandestine nuclear activities.

Missile Proliferation

We will maintain our strong support for the Missile Technology Control Regime. We will promote the principles of the MTCR Guidelines as a global missile nonproliferation norm and seek to use the MTCR as a mechanism for taking joint action to combat missile proliferation. We will support prudent expansion of the MTCR's membership to include additional countries that subscribe to international nonproliferation standards, enforce effective export controls and abandon offensive ballistic missile programs. The United States will also promote regional efforts to reduce the demand for missile capabilities.

The United States will continue to oppose missile programs of proliferation concern, and will exercise particular restraint in missile-related cooperation. We will continue to retain a strong presumption of denial against exports to any country of complete space-launch vehicles or major components.

The United States will maintain its general policy of not supporting the development or acquisition of space-launch vehicles in countries outside the MTCR.

For MTCR member countries, we will not encourage new space-launch vehicle programs, which raise questions on both nonproliferation and economic viability grounds. The United States will, however, consider exports of MTCR-controlled items to MTCR member countries for peaceful space launch programs on a case-by-case basis. We will review whether additional constraints or safeguards could reduce the risk of misuse of space launch technology. We will seek adoption by all MTCR partners of policies as vigilant as our own.

Chemical and Biological Weapons

To help deter violations of the Biological Weapons Convention, we will promote new measures to provide increased transparency of activities and facilities that could have biological weapons applications. We call on all nations — including our own — to ratify the Chemical Weapons Convention quickly so that it may enter into force by January 13, 1995. We will work with others to support the international Organization for the Prohibition of Chemical Weapons created by the Convention.

Regional Nonproliferation Initiatives

Nonproliferation will receive greater priority in our diplomacy, and will be taken into account in our relations with countries around the world. We will make special efforts to address the proliferation threat in regions of tension such as the Korean peninsula, the Middle East and South Asia, including efforts to address the underlying motivations for weapons acquisition and to promote regional confidence-building steps.

In Korea, our goal remains a non-nuclear peninsula. We will make every effort to secure North Korea's full compliance with its nonproliferation commitments and effective implementation of the North-South denuclearization agreement.

In parallel with our efforts to obtain a secure, just, and lasting peace in the Middle East, we will promote dialogue and confidence-building steps to create the basis for a Middle East free of weapons of mass destruction. In the Persian Gulf, we will work with other suppliers to contain Iran's nuclear, missile, and CBW ambitions, while preventing reconstruction of Iraq's activities in these areas. In South Asia, we will encourage India and Pakistan to proceed with multilateral discussions of nonproliferation and security issues, with the goal of capping and eventually rolling back their nuclear and missile capabilities.

In developing our overall approach to Latin America and South Africa, we will take account of the significant nonproliferation progress made in these regions in recent years. We will intensify efforts to ensure that the former Soviet Union, Eastern Europe, and China do not contribute to the spread of weapons of mass destruction and missiles.

Military Planning and Doctrine

We will give proliferation a higher profile in our intelligence collection and analysis and defense planning, and ensure that our own force structure and military planning address the potential threat from weapons of mass destruction and missiles around the world.

Conventional Arms Transfers

We will actively seek greater transparency in the area of conventional arms transfers and promote regional confidence-building measures to encourage restraint on such transfers to regions of instability. The U.S. will undertake a comprehensive review of conventional arms transfer policy, taking into account national security, arms control, trade budgetary and economic competitiveness considerations.